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ABSTRACT

This volume of biology units has been prepared with an introductory college level audience in mind. The intents have been to offer a variety of topics drawn from several sources and to enable instructors to use the materials at the level of their students. The units not only encourage, but some require, inductive teaching methods. Topics are: (1) The Nature of Science; (2) Evolution; (3) The Cell; (4) Reproduction, Growth, and Development; (5) Genetics; (6) Metabolism and Regulatory Mechanisms; (7) The Variety of Living Things; and (8) Ecology. Also included in the work are teacher resource materials involving curriculum planning, teaching suggestions, evaluation techniques, and bibliographies of topics covered. (CP)

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INSTITUTE FOR SERVICES TO EDUCATION, INC.

TEACHER'S GUIDE TO CLASSROOM DISCUSSIONS FOR BIOLOGY

The Thirteen Colleges Curriculum Program
The Five College Consortium
The Eight College Consortium

Edited by
CHARLES M. GOOLSBY, Ph.D.
Senior Program Associate for Biology
Institute for Services to Education
Washington, D. C.
and
Professor of Biology, Northeastern University,
Boston, Mass.

DAN A. OBASUN, Ph.D.
Program Associate for Biology
Institute for Services to Education
Washington, D. C.

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FRONTISPIECE

Section through a kidney tubule of the rabbit. X6000. Osmic acid fixation, uranyl nitrate staining. Photographed with the RCA 3H electron microscope by C. M. Goolsby.

LEGEND

CaL — Capillary lumen

Ci — Cilium

CL — Cell limit

Ds — Desmosome

Mi — Mitochondrion

Mv — Microvillus

Nu — Nucleus

NuP — Nuclear pore

Ps — Polysomes

TuL — Tubule lumen

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CONTRIBUTING AUTHORS

REBECCA B. ANDERSON, M. S.
INSTRUCTOR OF BIOLOGY
FIVE COLLEGE CONSORTIUM
SOUTHERN UNIVERSITY
SHREVEPORT, LOUISIANA

ROBERT J. ANTHONY, M. S., M. ED.
ASSISTANT PROFESSOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
JACKSON STATE COLLEGE
JACKSON, MISSISSIPPI

HAROLD E. BANKS, M. S.
INSTRUCTOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
LINCOLN UNIVERSITY
LINCOLN UNIVERSITY, PENNSYLVANIA

THADDEUS V. BEASLEY, M. S.
INSTRUCTOR OF BIOLOGY
FIVE COLLEGE CONSORTIUM
ELIZABETH CITY STATE UNIVERSITY
ELIZABETH CITY, NORTH CAROLINA

CHARLES H. BENNETT, M. S.
INSTRUCTOR OF BIOLOGY
FIVE COLLEGE CONSORTIUM
TEXAS SOUTHERN UNIVERSITY
HOUSTON, TEXAS

PURCELL B. BOWSER, M. S.
ASSISTANT PROFESSOR OF BIOLOGY
FLORIDA A & M STATE UNIVERSITY
TALLAHASSEE, FLORIDA

JIMMIE L. CAL, M. ED.
INSTRUCTOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
ALABAMA A & M COLLEGE
NORMAL, ALABAMA

MARTIN J. CAREY, M. S.
INSTRUCTOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
CLARK COLLEGE
ATLANTA, GEORGIA

ELIZABETH D. CLARK, M. S.
ASSISTANT PROFESSOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
NORTH CAROLINA A & T STATE UNIVERSI
GREENSBORO, NORTH CAROLINA

IRENE R. CLARK, M. ED.
ASSISTANT PROFESSOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
FLORIDA A & M STATE UNIVERSITY
TALLAHASSEE, FLORIDA

WILLIE D. CLARK, M. S.
ASSISTANT PROFESSOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
BISHOP COLLEGE
DALLAS, TEXAS

ROBERT M. COBBINS, M. S.
ASSISTANT PROFESSOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
SOUTHERN UNIVERSITY
BATON ROUGE, LOUISIANA

VALERIE P. FLEMING, M. S.
ASSISTANT PROFESSOR OF BIOLOGY
FAYETTEVILLE STATE UNIVERSITY
FAYETTEVILLE, NORTH CAROLINA

CHARLES M. GOOLSBY, PH.D.
SENIOR PROGRAM ASSOCIATE
INSTITUTE FOR SERVICES TO EDUCATION
WASHINGTON, D. C.

GEORGE W. GRAYSON, M. S.
INSTRUCTOR OF BIOLOGY
ALABAMA A & M STATE UNIVERSITY
NORMAL, ALABAMA

ROBIN M. GRIFFITH, M. A., M. A. T.
INSTRUCTOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
NORFOLK STATE COLLEGE
NORFOLK, VIRGINIA

MAE T. GROVES, M. S.
INSTRUCTOR OF NATURAL SCIENCE
TALLEDEGA COLLEGE
TALLEDEGA, ALABAMA

BENNYE HENDERSON, M. S.
INSTRUCTOR OF BIOLOGY
DEPARTMENT OF BIOLOGY
JACKSON STATE COLLEGE
JACKSON, MISSISSIPPI

VERSIA L. LACY, M. S.
ASSOCIATE PROFESSOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
BISHOP COLLEGE
DALLAS, TEXAS

PERRY V. MACK, M. S.
INSTRUCTOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
BENNETT COLLEGE
GREENSBORO, NORTH CAROLINA

CHANDRA P. MISRA, PH. D.
PROFESSOR OF BIOLOGY
FIVE COLLEGE CONSORTIUM
SAINT AUGUSTINE'S COLLEGE
RALEIGH, NORTH CAROLINA

DAN A. OBASUN, PH. D.
PROGRAM ASSOCIATE
INSTITUTE FOR SERVICES TO EDUCATION
WASHINGTON, D. C.

FRANK RUSINKO, M. S.
ASSISTANT PROFESSOR OF BIOLOGY
CLARK COLLEGE
ATLANTA, GEORGIA

WASI M. SIDDIQUI, PH. D.
PROFESSOR OF BIOLOGY
BISHOP COLLEGE
DALLAS, TEXAS

ALICE C. SMITH, M. S.
INSTRUCTOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
TENNESSEE A & I STATE UNIVERSITY
NASHVILLE, TENNESSEE

EHSAN A. SYED, M. S., M. S.
INSTRUCTOR OF BIOLOGY
BISHOP COLLEGE
DALLAS, TEXAS

MURIEL E. TAYLOR, M. A.
PROFESSOR OF BIOLOGY
THIRTEEN COLLEGE CURRICULUM PROGRAM
TALLADEGA COLLEGE
TALLADEGA, ALABAMA

HAROLD W. TOLIVER, M. S.
INSTRUCTOR AND CHAIRMAN OF BIOLOGY
FIVE COLLEGE CONSORTIUM AND
DEPARTMENT OF BIOLOGY
LANGSTON UNIVERSITY
LANGSTON, OKLAHOMA

PREFACE

At the time that the Curriculum Resources Group of the Institute for Services to Education held its first summer conference for the teachers of the Thirteen Colleges Curriculum Program in the summer of 1967, there was a feeling among the member institutions that they could turn out better students, students more able to meet the competition for jobs needed for survival. There has been a gap between the academic attainment of many high school graduates, especially those from rural areas, and the expected levels for such graduates that is actually a tradition. The black college, in particular, has for decades found that it has had to engage in "gap-closing" activities in order to produce college graduates who could continue to meet the competition for jobs. Of course, as in any human endeavor, they were not able to achieve this 100%, nor did they feel that they were going about it in 100% the right way. It was a period, too, when the Civil Rights movement was spurring integration, including more widespread integration of public elementary and secondary schools as well as colleges in the south. The future of black colleges was being weighed, perhaps even without their permission. Some colleges realized that it would be very desirable to improve the quality of their graduates.

At the same time, although it may not have been admittedly a very direct cause, there was an increasing demand heard from students in colleges all over America. As the 1960's dawned, the "silent generation" became a militant generation with confrontation politics its usual tool instead of debates in impotent student councils. Although there was only a vocal minority of students voicing protestations about teaching practices in American colleges, including the predominantly black colleges, their points of view were apparently shared by the great "silent majority" of the other students. These students were not content just to sit and listen to the opinions of their teachers nor to the recitation of facts without the opportunity to ask questions about the application and relevance of points of view to the life that these students perceived as being theirs. There was an increasing restlessness about administrative procedures as well and a growing insistence that the student be allowed to have a larger participation in the formulation of his educational plans so that his attendance at college would contribute more and more to his personal and career goals. These goals were being shifted from that of mere personal achievement to an enlarged participation in the life of the community as evidenced by students' responses to opportunities for work in the Peace Corps, the Civil Rights movement and the Black Community as put forth by various advocates of Black Power. The Thirteen College Curriculum Program in part represents a response to and recognition of the legitimacy of these protestations as well as the recognition by the colleges that the materials and methods of teaching this generation of students would represent an almost radical departure from the traditional means and aims of higher education in the United States. Furthermore, students in predominantly black colleges were being faced with increasing competition for the jobs available to college graduates. A growing national population, a rapidly expanding technology, the burgeoning of the value of the gross national product, and other factors, indicated that the quality of education of the black college graduate had to be improved in order for these young people to gain and keep the jobs that mean economic survival for their generation.

On the other side of the coin the high mobility of the American population, the pictorial presentation of life in the United States and around the world on television programs brings home to young people a kind of futility about a vigorous preparation for the future. Born in the era of the atomic bomb, the occupation of territories won in World War II, the Korean conflict, and the long, escalated and deadly war in Viet Nam, they are torn between becoming usefully educated and the uselessness of becoming educated if their end is to lie dead in some far-off jungle. Yet, amid their torment and despair over these circumstances, young men who can afford to go to college can do so with the hope that they may escape the fate that awaits the less pecunious and intellectually-prepared of their generation. These young men could look forward to deferments from military service as long as their college grades were acceptable to their local selective service boards, but no more.

These conditions tend to marshall the demands of students around the ideas that if they must study, in fact just to stay alive, (much less contribute to the solution of the non-military problems of our time) their education must be able to help them survive today. It cannot be highly abstract--something that they would take out into the real world and test and then finally gain experience and perhaps success. They see success depicted on television, they hear the great ideas of our time, they see the personalities that shape the news in politics, business, education, science, and all other areas of living. Yet, in making the college experiences of students relevant to their lives the procedure must still remain "education" as compared with "training." The technology of our time advances too rapidly to concentrate solely on how to do practical things. The nature of the problems facing our society must still be understood and the methods by which successful solutions have been evolved in the past must still be communicated if indeed the college experience will be relevant for the present generation.

The present volume has been written and compiled as an aid to teachers of introductory biology who feel a commitment to provide the best education in this area for their students. There is nothing magic about the materials, for they may be used in ways not intended by the authors. Their strength is that they not only permit, but usually require, inductive teaching methods. Also, since these materials are not related to a single book, but many books, there is great flexibility, permitting the teacher to use them at the level of the highest abilities of his students. They also reflect the view that it is better to teach some topics well than many topics poorly. Therefore, the topics selected are those in each area of greatest interest to students, teachers and the development staff. This means some important topics have not been included, but also that better understanding in addition to memory is sought. Of equal importance is the aim of having students become familiar with the way scientists gather information and reason about it so that they may live freer of fear about natural biological phenomena in relation to themselves personally and as members of society.

We express our appreciation to the teachers who helped formulate the units of study, for their tireless efforts, their enthusiasm and awareness of student interest. They are the contributing authors. We also would like to thank Dr. Edward J. Brantley, Coordinator of the Thirteen College Curriculum Program, Dr. Clesbie R. Daniels, Director of the TCCP at Bishop College, for reading Chapter 1 and making many helpful suggestions, and Dr. Joseph Turner, Dr. J. Thomas Parmenter of the ISE evaluation staff, and Miss Patricia Parrish of the ISE editorial staff for reading Part I and making many valuable suggestions.

Charles M. Goolsby

Dan A. Obasun

Washington, D. C.
June, 1971

ABOUT THE INSTITUTE FOR SERVICES TO EDUCATION

The Institute for Services to Education was incorporated as a non-profit organization in 1965 and received a basic grant from the Carnegie Corporation of New York. The organization is founded on the principle that education today requires a fresh examination of what is worth teaching and how to teach it. ISE undertakes a variety of educational tasks, working cooperatively with other educational institutions, under grants from government agencies and private foundations. ISE is a catalyst for change. It does not just produce educational materials or techniques that are innovative; it develops, in cooperation with teachers and administrators, procedures for effective installation of successful materials and techniques in the colleges.

ISE is headed by Dr. Elias Blake, Jr., a former teacher and is staffed by college teachers with experience in working with disadvantaged youth and Black youth in educational settings both in predominantly Black and predominantly white colleges and schools.

ISE's Board of Directors consists of persons in the higher education system with histories of involvement in curriculum change. The Board members are:

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ABOUT THE THIRTEEN-COLLEGE CURRICULUM PROGRAM

From 1967 to the present, ISE has been working cooperatively with the Thirteen-College Consortium in developing the Thirteen-College Curriculum Program. The Thirteen-College Curriculum Program is an educational experiment that includes developing new curricular materials for the entire freshman year of college in the areas of English, mathematics, social science, physical science, and biology and two sophomore year courses, humanities and philosophy. The program is designed to reduce the attrition rate of entering freshmen through well thought-out, new curricular materials, new teaching styles, and new faculty arrangements for instruction. In addition, the program seeks to alter the educational pattern of the institutions involved by changing blocks of courses rather than by developing single courses. In this sense, the Thirteen-College Curriculum Program is viewed not only as a curriculum program with a consistent set of academic goals for the separate courses, but also as a vehicle to produce new and pertinent educational changes within the consortium institutions. At ISE, the program is directed by Dr. Frederick S. Humphries, Vice-President. The curricular developments for the specific courses and evaluation of the program are provided by the following persons:

Course	ISE STAFF
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	Dr. Joseph Turner, Senior Research Associate
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In addition, Miss Patricia Parrish serves as general editor of the curriculum materials as well as an Administrative Assistant to the Director. Mrs. Joan Cooke is Secretary to the Director.

The curriculum staff is assisted in the generation of new educational ideas and teaching strategies by teachers in the participating colleges and outside consultants. Each of the curriculum areas has its own advisory committee, with members drawn from distinguished scholars in the field but outside the program.

The number of colleges participating in the program has grown from the original thirteen of 1967 to nineteen in 1970. The original thirteen colleges are:

Alabama A and M University	Huntsville, Alabama
Bennett College	Greensboro, North Carolina
Bishop College	Dallas, Texas
Clark College	Atlanta, Georgia
Florida A and M University	Tallahassee, Florida
Jackson State College	Jackson, Mississippi
Lincoln University	Lincoln University, Pennsylvania
Norfolk State College	Norfolk, Virginia
North Carolina A and T State University	Greensboro, North Carolina
Southern University	Baton Rouge. Louisiana
Talladega College	Talladega, Alabama
Tennessee State University	Nashville, Tennessee
Voorhees College	Denmark, South Carolina

A fourteenth college joined this consortium in 1968, although it is still called the Thirteen-College Consortium. The fourteenth member is

Mary Holmes Junior College	West Point, Mississippi

In 1971, five more colleges joined the effort although linking up as a separate consortium. The members of the Five-College Consortium are:

Elizabeth City State University	Elizabeth City, North Carolina
Langston University	Langston, Oklahoma
Southern University at Shreveport	Shreveport, Louisiana
Saint Augustine's College	Raleigh, North Carolina
Texas Southern University	Houston, Texas

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UNIT 8 - ECOLOGY By Robert J. Anthony, Jimmie L. Cal, Willie M. Clark, Robin M. Griffith, Mae T. Groves, and Ehsan A. Syed. Foreword by Ernest Ruber

INSTITUTE FOR SERVICES TO EDUCATION, INC.

TEACHER'S GUIDE TO CLASSROOM DISCUSSIONS FOR BIOLOGY

PART I

PRINCIPLES FOR STRUCTURING THE COURSE

CHAPTER 1 -- CURRICULUM PLANNING FOR EXCELLENCE IN EDUCATION

Imagine, if you will, two stone-age families. One is headed by a Mr. Chips and the other by Mr. Block. Both make stone axe heads, but Mr. Chips makes a sharper edge on his blades than does Mr. Block. The result is that Mrs. Chips can cut the firewood more easily than can Mrs. Block and she more easily skins the game Chips brings home.

In addition, Chips seems to be more confident that he will survive his encounters with bears or whatever he meets in the forest. He also seems to have more time for sitting around his fire sucking on the bones of his last barbecue,telling of his exploits (probably a bit boastfully and with considerable exaggeration), or strengthening the defenses of his domicile.

Block might reasonably consider Chips to have a better life than his, and upon further mulling over of the idea, probably concludes that if he could make his axes sharper, perhaps, he might enjoy the same benefits as his neighbor. He, thus, senses the need for education, that is, to learn how to do something he apparently doesn't know how to do at the time. So, in his highly motivated state for learning, he persuades Chips to show him how to make a better axe. Chips agrees, but on the condition that Block pay him a hundred rabbits. Thus, a professional school is born. More neighbors come, and Chips finds that he gets so much game from his students that he doesn't need to go hunting anymore--he has become a professional educator.

Part of the process for making sharp stone axes consists of heating a stone in the fire and dousing it with cold water before striking it with another unheated rock. While carrying out this process, two students of axe-smithing discover that the rocks give up metals--gold or copper. One takes to making axes of gold and becomes known as Mr. Goldsmith, and the other makes axes of copper and becomes known as Mr. Coppersmith. Their axes are good, but expensive. They are sharper than stone axes, but are somewhat easily dented and dulled when they hit hard objects, like a skull. However, it is easier to resharpen them.

Mr. Chips, not being very good at all at making axes of gold or copper, takes to the social persuasion of his friends to the view that stone axes are superior to the new-fangled metal ones. He forms his stone-axe students into a club or guild for the production and sale of stone axes and begins to recruit more students to stone axe-smithing so that he will not have to go back to the life of the hunter. Goldsmith counters by diversifying his production to include ornamental dodads for decorating wives and sweethearts and Coppersmith moves to meet competition by producing cups, pots and kitchen knives.

A whole new technology is created, a new business situation is generated, and the need for more and more specialists for the making of stone axes, gold jewelry and copper pots increases. Different kinds of schools are needed--

one for training smiths, another for accounting for the raw materials, production and payment of workers, the evaluation of profits, and still others for training musicians, dancers, artists, writers, and the like, to provide entertainment, not only for the now affluent, but also for the common man as well. The generalized Mr. Chips and Mr. Block become superceded by a complex, interdependent group of specialized individuals differentiated into a society, a culture, a community...and at the heart of it all is the school.

In the above parable we note that as technology changed the society and created newer and better ways of doing things, that there were conservative forces acting to retain that which was old, tried and true--the old stone axes--reliable, but quite useless for the finer work and more sensitive aesthetic needs of a more refined culture. American education is a far cry from the stone-aged school, but the purposes of the school and its position in the culture remain at the heart of the system. The school is not only a place to learn how to do things, but a place to learn about solving problems, real and theoretical, as well as a place to discover things that are useful to mankind (for both good and bad social purposes). The "goodness" or "badness" of education, then must revolve about its ability to prepare people (of whatever age) to do something useful and desirable in the society. Frequently in America this purpose has been captured and controlled by individuals and special interest groups to produce a preponderance of graduates with a particular skill, point of view, orientation, or motivation toward their own personal gain, and the exploitation of individuals for the benefit of the special interest. In effect, American education has had at various times its numerous "stone axe" advocates pulling against the strivings in education for newer ideas and techniques. In order to keep from slipping too far back, schools plan curricula that are as forward-looking as liberal educators are permitted to make them, and which contain compromises with the "stone axes" in our system of schools. Because of this, there has to be careful planning for progress. Good planning does not assure a good program of education, but no planning is almost assured of resulting in the individual school returning to a ground state of "stone axes."

AN OUTLOOK ON CURRICULUM PLANNING

1. What is "good" education? Some economists would like for it to produce both workers and managers. Some national planners would like for it to generate people with imagination and new ideas for the solution of the socio-political problems on one hand, and a large mass of unquestioning followers on the other. For many teachers it means sharing with the younger generation what they have found to be useful and workable in their experiences (as a rule). For students in America it means an education that helps them to fit into the schemes laid out by their elders on one hand, and the ability to forge ahead into new areas of endeavor and concept (not yet fully accepted by most of the preceding generation) on the other hand.

There is much discussion about the generation gap. It does exist. Many people believe it is a characteristic of adjacent generations (of an average

age difference of about ten years), when most of what they observe are the the progressive differences between three or four or more decades of separation. That is to say, the change taking place in the viewpoints of 16-year olds is gradual over a 10-year period but radical over a 30 or 40-year period. The gap is reduced by the degree to which adults have moved with the changes in the technology and society, so that most 20-year olds may find that they have little difficulty with the generation gap when dealing with their college teachers who are either only slightly older, or 40 years older (provided that those teachers have not been assiduous conservatives clinging to their "old stone axes"). Because teachers must communicate with their students most academicians find it necessary to constantly broaden their experiences along with those of young people they teach. The result is that at 70 they understand the 20-year old's experience, but with the advantage that they may evaluate it in the light of a considerable evolution and history.

We feel that the best education is one in which:

> Teachers make fresh examinations and assessments of the teaching materials as to what is important, interesting and relevant,
>
> the curriculum includes items that are attractive and interesting to the student, and in which
>
> there is an effort made to fit these two things together.

In this way the experience of teachers can be used to observe the changes occurring over a span of time and perhaps see some directions of development. Unfortunately, human endeavors frequently do not follow the expected, so that there is no guarantee that the more experienced and even more knowledgeable adults will make accurate forecasts about what will be the most important or useful things at some future time. The problems are many, however, so that if a student has an interest in any problem area (discipline), teachers can help develop skill, thinking and information about that problem area in students. In this set the ways of thinking are important for the solutions to problems may not sometimes be found by traditional methods. However, some traditional skills and endeavors are necessary in order to live in a society in which a good proportion of the members belong to the older, more experienced group that make current policy and regulate current practice. For example, one must use traditional banking practices, but may use the money he has in very untraditional ways.

In our view, than, a "good" education (or a quality education) is one in which the above things are accomplished. "Poor" education, or "poor quality" education, tries to fit students into fixed patterns of behavior and does not take their interests and aspirations into consideration.

2. The curriculum must be flexible and able to change to meet new demands and needs in our society. The changes in technology, in the interests of students, and what the culture makes important to people are features to which college curricula respond. A curriculum should not be considered good for several years, but, instead, should be revised periodically. In fact, there should be continual study of what should be added and what should be dropped from the curriculum. This does not mean that things must be changed

just for the sake of changing them. However, where there are alternatives, it does add variety and change of pace to use different choices at different times. Very often curriculum workers make changes in curriculum under the guise of "innovation" when, in fact, they are merely using materials that have been previously dropped or are in an alternate, unused category.

An example of curriculum change due to changed interests concerns space. American and Russian exploration ofthe moon has created a lot of interest in the moon, its origin, composition, and the technology of space travel. These then become new areas for inclusion in curricula. But since most courses are limited by time, that is, the time in an academic quarter or semester, it means that some other topics must be considered in less detail or dropped if space research is added. An example of curriculum change because of a change in information would be those dealing with our ideas on the states of matter. For some years it has been taught that water going from ice to water to steam does not undergo chemical changes. Now (1970) there have been several research articles dealing with the amount of hydrogen bonding in water at various temperatures and its effect on the heats of fusion and vaporization, surface tension, and ability to hold solutes in solution that depend upon chemical changes (hydrogen bonding).

3. No master plan will serve all situations adequately. In designing curricula for the college, we recognize that colleges tend to feel that they are autonomous bodies. Through consortium arrangements, they come to feel support for some ideas and actions. Quite apart from what the higher administration wants in colleges, department chairmen and teaching faculties tend to want to do their favorite things (which may include some "stone axes"). In the ISE-sponsored types of curriculum the interests of students is a paramount consideration and these interests vary from school to school. The present solution lies in providing a curriculum broad enough to permit selection of a course that can be varied within the tested materials in order to meet these varying student and teacher interests.

4. A curriculum is the result of many groups working together. Curriculum development is a process that takes into consideration the interests of students, of teachers, of curriculum planners, and of the private and public funding agencies that support the project. If the result is to be useful, it requires the honest participation of all of these groups. New curricula mean new opportunities to eliminate student boredom from dull or uninteresting aspects of subjects being introduced. There is no such thing as useless information, so what does it matter if the topic seems "not important" to the teacher. If the student thinks that it is important or relevant, then it is. The experienced teacher also knows, however,that there are some "basic" ideas and techniques that students need to know if they are going to succeed, and if there is to be contact with present reality as students go off into the wild, wild blue of their own interests. College teachers seem to want (in the main) to teach the more specialized advanced courses or to teach that which they learned long ago as "fundamentals." It is best to begin within the experience area of the student. He must then be coached by teachers to expand the horizons of his perceptions and knowledge in order for him to have the broad viewpoints which will provide flexibility and adaptability in the kind of society that he

finally comes to work within. Curriculum workers and specialists must keep in touch with the reality of student thought and aspiration. They must also be aware of the general tendencies of teachers to be sympathetic toward change as well as their inability to overcome the inertia of exchanging their favorite ideas and favorite methods (no matter how much of a "stone axe" they may be) in favor of the more refined and more sensitive teaching techniques, and the latest confirmed information.

While the contributions of each of the mentioned groups is needed, curriculum development is not the exclusive property of any one of these groups.

SOME DEFINITIONS

We have been using the word "curriculum" as though it was universally understood in the same ways that we will be using it.

The curriculum encompasses all of the teaching or of the learning opportunities provided by the teacher, and, as such, includes the course content, the technical teaching apparatus, and the teaching method or style.

The amount of materials offered by the teacher is greater than individual students usually assimilate, so that they get graded accordingly. The term "learning opportunities" reflects the idea that it is the students' responsibility to recognize and take advantage of the reading, discussions, and other experiences offered. A complement of this idea of the school is as a place where teaching takes place. We will elaborate upon the differences between didactic and inductive teaching later, but in general, teaching is used here to mean that someone helped the student to arrive at understanding about the topics being considered. The teaching presented represents the curriculum had. If the student was inattentive, absent, or couldn't see or hear, then he will not have participated in part of the "curriculum had," so what he ends up with is the curriculum experienced. Curriculum planners develop a curriculum planned, but there are opportunities for losses due to entropy (disorganized energy) between it and the curriculum experienced by the student. Perhaps more important is the fact that curriculum planning results in the kind of curriculum provided. For example, in college the course of lectures appears to have great efficiency for the teacher but not for the student so that the well-planned lecture course may still be one with great entropy and, therefore, with great inefficiency. The student perceives a per cent, say 10 per cent, of what is said, so that by piling 1000 items of information on him he may learn 100 of them. Curricula designed around inductive teaching is more efficient for arriving at understanding so that only about 500 items of information, for example, is needed to bring learning up to 100 items. The entropy in inductive teaching methods is found in the amount of information that can be transferred per unit of time, but other kinds of factors, such as better perception, more detailed or complete information transfer, and the "ability to think" may make this a more valuable method in the end.

A curriculum plan is the arrangement in advance of teaching-learning situations for a particular group of students. The curriculum is the same as the program of the course, so that the curriculum plan is the intended structure for the course. The ISE courses are planned out of the available units of study. These have been tested for their general interest to students. The ISE units are then usable in a variety of orders but the teacher should, and in most cases is asked to, have a curriculum plan before the term begins. At the consortium level, curriculum decisions are made during the summer conference as to the content, teaching aids, laboratory work and the like.

A curriculum guide or teacher's guide is a written curriculum plan. Actually, these terms have broad interpretations. Such guides will contain statements of curriculum scope, objectives, content, resources, and the like, supplemented by newsletters and bulletins.

Factors Affecting Curriculum Development

There are several determinants affecting the structure of the curriculum--the students. Among these we may include:

the aims of the college,

the nature of knowledge,

the process of learning, and

the impact of the society.

These determinants serve as guides to curriculum planners which will include the concerns of professional educators, such as the ISE staff, academic administrators, and teachers, students, and funding grantors. All of these participate in curriculum decisions as to the characteristics of a good curriculum, organization and selection of content, the style and method of instruction, and what parts will be left to the planning of teachers for particular classes. These decisions result in curriculum plans for the instruction to be offered by the teacher and shared in by the student.

What are the Forces Affecting Curriculum Decisions?

The decisions about what goes into a curriculum are finally influenced by several forces. These include:

Traditions

The Federal Government

Foundations

Secondary Education

Accreditation

Teachers

Testing Programs

Educational Research

Public Interest

Special Interest Groups

Authors and Publishers

Critics of American Education

Tradition is important in education because it reflects the important methods by which the young have been educated (well and poorly) in the past. The array of methods is the range of methods whereby groups of young people have responded well to education. In some cases they succeeded in spite of the method used. In general the methods can be divided into the traditional (those that "show me") and liberal (those that encourage thinking-through and problem-solving). Some milestone educators in the liberal tradition are listed in Chapter 2. In general the liberal educators maintain that there are better ways to organize learning experiences so that learning is faster, less painful, more thorough, and so forth.

In the United States there is a strong tradition favoring public education. There were about 20 college graduates in the pilgrim group of 1620 that founded the Massachusetts Bay Colony. It was there that John Bridge founded the first public school, there the first American university was founded, and there the first high school was organized. Curriculum has become more complex as the nation has grown and its technological demands have increased. It has been varied to make education an effective force in the democratic process, and the open socio-economic system in America.

On the negative side, tradition operates to hold back progress. The first objection many teachers (and even laymen) make to a new curriculum proposal is "We've never done that. We've seen what we have work— why do we have to change?" In reviewing what is "best" one is not evaluating what is "oldest" or "newest."

The Federal Government does not operate a public education system, but that does not mean that it does not have an influence upon what happens in the public schools and, indeed, what happens in colleges, universities and research institutions. The National Defense Education Act of 1958, and additions to the Act to 1964, provided for special financial assistance to improve instruction in science, mathematics and modern languages, and to improve guidance and counselling services. The National Defense Education Act Amendments of 1964 broadened the scope of the Act to include "other critical subjects" in Title III (equipment and materials): history, civics, geography, English and reading, and to provide for teacher institutes

(Title XI) in history, geography, modern foreign languages, reading, and English, as well as for teachers of disadvantaged youth, and for library personnel and educational media specialists. It can be argued that Federal agencies do not really control curriculum planning since colleges do not have to accept grants for special purposes, and, therefore, do not have to meet whatever requirements or controls the grants stipulate. But the colleges and universities have usually been eager to take advantage of any financial aid possible, so that to the extent requirements are stipulated and met, there are forces on curriculum planning emanating from the Federal governmental structure. The requirements of the granting agencies are not usually considered to be unreasonable, but many educators, especially in the public school systems, consider the system of Federal grants to favor certain curriculum areas. In 1964 the Educational Policies Commission of the NEA recommended that "in view of the failure of the Congress to establish general nation-wide Federal aid to education" that "education leadership devote immediate and detailed attention to the improvement and spread of categorical aids."[1] The Education Act of 1965 broadened the scope of aid.

The participation of the Federal Government in educational reform has grown steadily. In his Message on Education Reform to the Congress (March 3, 1970), President Nixon indicated that "...the 1971 budget increases funds for educational research by $67 million to a total of $312 million." Other branches of the federal government spend considerable amounts for education. Figures for 1968 are as follows:

Area	Expenditure in $ billions	Equivalent Man-years
Education	.190	4,500
Health	2.400	59,000
Agriculture	.800	26,000

Foundations and other private philanthropic organizations have supported a large number of improvements in education. In general they have chosen to support projects which have not been adequately funded by government agencies. While foundations expect that recipients of their funds will use them for the agreed-upon purposes, it is usually easier to change directions if a fruitful course of action is indicated. Recent tax laws have been written to change the tax-exempt status of foundations under certain circumstances. The effect of these laws, then, has been to make foundations want more assurance that their funds will not be expended in ways that will make them lose their tax-exempt status. While Foundations and other philanthropy have supported operating expenses for some educational endeavors, their greatest significance lies in the fact that they have funded some projects of an experimental nature which later became accepted.

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[1] The Educational Policies Commission, Education Responsibilities of the Federal Government (Washington, D. C.: National Education Association, 1964) p. 18.

[2] AASA Committee on Foundations (Roy M. Hall, Chairman) Private philanthropy and public purposes, Washington, D. C., American Association of School Administrators, 1963, p v.

A report by the Committee on Foundations of the American Association of School Administrators (1963)[2] says that there are more than 15,000 private philanthropic foundations with total assets of around $12 billion, from which grants amounting to about $700 million are made each year. The private foundations, however, do not have to report to a legislative body like Federal agencies eventually have to, so they do not feel the need to control curriculum projects which they support. The AASA report went on to say:

> "Hopefully, the foundations, in cooperation with school administrators and other educational leaders, will develop a more detailed set of standards for professional practices to be followed by the donors and the recipients of grants. Such criteria would do much to ensure, insofar as is possible, that today's best practice becomes tomorrow's common practice. If such criteria or ethics are faithfully observed, new truths may be found, more and better educational results secured, and the objectives of a free society more readily safeguarded."

Harold Monson (1970)[5] has reviewed the situation since 1963, saying:

> "Since 1963 several factors have entered the picture to sharply change the current role of Foundations in the field of public education and to give school administrators, Boards of Education, schools of education, and governmental agencies responsible for the financing and operation of public education, additional urgency in examining both the role of the foundations and the role of the school administration in their relationship to such philanthropy."

Monson cites these factors:

1. The continued growth of both the number and the assets of the foundations.

   "By the end of 1968 there were more than 30,000 such organizations in existence in the U. S. possessing assets ranging in estimated value of from 40 to 50 billion dollars, and expending annually in excess of $1.5 billion for programs and related expenses."[6]

2. The increasing cost of public education and the search on the part of local, state and Federal governments for greater tax bases and tax income to support the increasing demand for better schools and services.

3. The recent entry into the field of more active support of education, by the Federal Government, exemplified by

   - The supply to regional centers and the U. S. Office of Education of large sums of money for developing innovations and research in education, evaluation of current and new practices, and various forms of compensatory education and the dissemination of information derived from all of these.
   - Special emphasis on the improvement of education for the disadvantaged. This has taken the pressure off foundations for experimental support but the increased costs of operation have shifted the burden to that area.
   - A sharp change in the role and priorities of the purposes and nature of the grants given by the larger foundations, which generally adjust their giving according to their own concepts of the needs of the society they serve.

Secondary Schools interact with colleges, tending to provide courses that are required for college entrance. Conversely, most of the national curriculum projects through the 1960's have centered upon the secondary schools, so that they have a variety of innovative, modern courses in science, mathematics, and other areas. This increases the spread of backgrounds brought to college by entering freshmen, with rural youth generally lagging in their preparations while city youth are more advanced, having been exposed to many topics in traditional freshman courses, including biology courses, where the curriculum improvement programs have operated. This places some responsibility on curriculum planners to evaluate what is "freshman" level in the light of the kinds of curriculum students have been exposed to in secondary schools. Such an examination would almost certainly lead to revision of freshman experiences to include some normally in the exposure of upperclassmen. This revision downward leaves the college faculty upset and irritated because some of their favorite topics are being discussed and some of their more interesting exercises are being done at the freshman level and they must find some new topics and experiments to do.

Accreditation by either state or regional agencies has done a lot to raise and keep higher standards in the secondary schools and in colleges and universities. During the first half of the century they did good work. There is some question now as to whether they examine themselves often enough to keep up with the fast pace of change in the society. The more generalized approach to courses and subject matter, such as in the ISE courses, runs across some of these "requirements." States require "U. S. History to 1865" but that may not be a relevant course today for freshmen. Similar situations exist with English literature and composition. The sciences are luckier, but there are problems with a half-year of biology or a half-year of physical science.

Teachers are a definite force in curriculum planning. Klohr and Frymier (1963) and others have observed that "significant progress in curriculum development may not be possible until there is a general strengthening of the teaching profession through shifts in the power structure. Clearly, research in the dynamics of curriculum change must cope with this kind of problem, no matter how complex it is."[3]

Testing Programs may have an influence on curriculum planning. There are two views to be considered. One is that the testing program should not have any effect upon the curriculum, but rather should be structured to survey curricula offered. Testing agencies make available questions from old tests but, in general, they do not reveal the content of the current test, so that courses will be presented in such a way that they will teach about life and the world, and not be constructed to pass the national, standard tests. The tests most likely to be taken by college students are the National Teachers Examination and the Graduate Record Examination. These are basically achievement-type tests. They are similar to the College Entrance Examination Board (CEES) examinations and the Scholastic Aptitude Test (SAT) taken by secondary school students. Because of the competition for acceptance to college, a number of high schools are known to teach courses designed to help their students pass these tests, under the impression that high scores will aid their acceptance at a college.

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[3] Klohr, Paul R. and Jack R. Frymeir Curriculum development: Dynamics of change. Review of Education Research, 33:318 (June, 1963).

The other view is that testing programs should have an effect upon the curriculum. By working closely with testing agencies, it is very possible to work out programs for this general purpose. Also, testing agencies will make available the bases of the validity of the tests and also provide current materials for study purposes by faculty and curriculum developers so that the educational purposes of institutions will be strengthened. This view is held to be important for certain groups of students. What is taken on a test should have been taught. Since it is totally impossible to teach all of a field of knowledge, why not teach those concrete principles or factors which relate to the realistic world in which one lives. This does not refer to specific items, but Black students should be prepared to pass national tests at high levels. Unless a young person is able to compete in a competitive world using the same approaches that others use, they begin at a disadvantage which is imposed on them by those individuals who should be helping them.[4]

Educational research has made considerable headway in the psychology of learning and the effect of teaching methodology on learning. These results are largely derived from investigation of primary and secondary school situations and are seldom for the college level. However, the principles operating for post-puberal high school youth are also applicable to college. Yet, virtually no college teachers outside of the College of Education have ever heard of these findings. College teaching is traditionally done by imitating one'e favorite professor, who was probably a great researcher but a poor teacher himself. The construction of contemporary college curricula, however, must take into consideration the theories of learning as well as modern teaching methods in the development of such a program. Because these procedures are not generally followed in college, the applicability of modern educational research to the college populations has only just begun, but no doubt will be a major component in the development of future curricular materials.

Public interest also is a factor in planning college curricula. Public interest in the environment has brought to the fore some ecology and environmental education courses which previously students had to be required to take in order to "round them out." The same is true of the public interest in drug addiction, mental health, the training of scientists and engineers, and the like. Since students are also part of the public, sensitivity to this sector constitutes an influence of the society on the curricular structure.

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[4] Brantley. E. J. (personal communication)

[5] Monson, H., 1970 "The role of foundations in public education: To what degree do they make policy or determine school programs andleadership?" Address to the 102nd Ann. Conv., Amer. Assoc. of School Administrators, Atlantic City, N. J., Feb. 18, 1970.

[6] Congressional Digest, May, 1969.

Special interest groups have affected the curriculum and will continue to do so--partly because they provide money to carry out the programs and partly because there is some basic worth in many of their ideas. For example, high school students, physically able to do so, are taught safe driving in school. Teachers in many states take some course which provides "alcohol and tobacco education." Civil defense education is also widespread in colleges, as is the Reserve Officers Training Corps.

Authors and publishers (or should it be publishers and authors) have a decided effect upon curriculum planning. American publishers expend a lot of money on the research and writing of textbooks, programmed materials, teaching machines, and many types of audiovisual aids. Most of these materials are excellent for the lecture course in college. However, there is very little in the way of textbooks and other reading resources which make inductive teaching more easily done at the college level. The authors and their publishers, therefore, are generally on the side of tradition, but this does not mean that they would not change if they thought that inductive teaching was the direction in which the educational system was headed.

Critics of education have been with us for a long time. No doubt "Mr. Chips," mentioned in the parable at the beginning of this chapter, had his critics. Since the Russians put Sputnik I into orbit in 1957, American education has had a larger number of critics than before that time, with such well-known individuals as Vice Admiral Hymann Rickover, James B. Conant and Spiro Agnew flinging down their gauntlets. Perhaps not so widely heard, but criticisms just as sound and true, are those raised by the leaders of the Institute for Services to Education: Dr. Samuel Proctor, Dr. Herman Branson, and Dr. Elias Blake, Jr. In fact, the ISE is not only a critic of American education but a catalytic agent for bringing about institutional reform and teaching reform in a group of colleges and universities.

The Results of Curriculum Planning

At least four things are developed by curriculum planning. These are curriculum plans, curriculum guides, changes in practices, and changes in people. The immediate aim of curriculum planning and curriculum guides is to help bring about changes in school and classroom practices. The most important changes are those brought about by the teacher as he or she carries out the plans and activities in the curriculum guide for the teaching of the class. The change may be small or large. Whether or not the new practice is better for that teacher or class than the old practice is a matter for evaluation, but the result of the curriculum change--a difference in course content and/or a change in teaching methods will be recognized by both teachers and students.

Changes in the behavior of the student (learning) is the ultimate goal of curriculum planning. Effective change from didactic to inductive teaching methods requires, in the end, a change in teachers. That is, not just a change on paper. Teachers who are themselves becoming more knowledgeable, more skillful, and more dynamic, can serve increasingly effectively as agents of change for their students. Therefore, changes in students and teachers are intimately related as ultimate products of the process of curriculum planning.

WHAT KINDS OF CONCERNS SHOULD DETERMINE WHAT GOES INTO THE CURRICULUM?

When curriculum planners meet to make curriculum decisions and curriculum plans, one of the kinds of questions that certainly reflect their concerns about what should go into a curriculum are:

> the kinds of students for which they are trying to plan educational experiences, and
>
> what kinds of issues are considered important by the society at that particular time.

This raises such questions as, how can these concerns be integrated with the ultimate aims of the school, and of education in the United States, and with the results of education research? The student and society and their concerns are considered to be so relevant to the curriculum planning process that these are customarily referred to as determinants of the curriculum.

The Student as a Determinant of the Curriculum

> "The fundamental factors in the educative process are an immature, undeveloped human being, and certain social aims, meanings, and values incarnate in the matured experience of the adult. The educative process is the due interaction of these forces. Such a conception of each in relation to the other as facilitates completest and freest interaction is the essence of educational theory."
> (John Dewey, 1902)

This statement is a classic (by definition, that which does not have to be changed). Even today, students are the primary object of the educational process. But why must the curriculum planner take account of students? Why not impose the values incarnate in the matured experience of the adult upon the learner?

Schooling (education) is at the heart of our democratic society, for without an informed and literate constituency it cannot survive politically, economically or socially. Therefore, a freely structured, broad, education which will permit the maximum development of each individual is essential for national and individual progress and individual flexibility and freedom.

Schooling must permit the individual to identify and develop his talents and capabilities as fully as that can be done for him in order for him to be fully educated. Therefore, the school must not impose a fixed curriculum of classical topics on the younger generation. Rather, it provides means for exploring possibilities without condemnation for failing to discover, and by giving social support to intellectual efforts in different and new directions. Education means the process of "leading out" (of ignorance) to enlightenment, and thus into freedom.

By developing fully the potentialities of each individual the whole society will be improved. As higher percentages of the society become better educated, the technical ability of the group to lead lives of more enlightened social living, better physical and mental health, and in the fuller pursuit of happiness are realized.

Today's students will be the operative members of the society in the near future. If they are to maintain the level of living attained by the present adults, they will have to acquire present levels of skill and even surpass the presently available skills, knowledge, insights, and moral character of contemporary society.

The motivational syndromes which characterizes the college student--his needs, his drives, his self-concepts, his perceptions, his aspirations and his excitations--constitutes foundation stones for selection and sequencing of learning experiences in the college curriculum.

Planning the college course, and arranging the learning experiences presented to students, ought to reflect something of what college students think will be important to them as they perceive their world, linked with the matured experience of the more adult. In so doing, the maturity, capacities and abilities of the learners should not be underestimated nor overestimated. Evaluation of the growth and development shown by students should not be measured against some such standard as the teacher's ability and experience, but against that which was possible, taking into consideration the potential development and growth and the amount of his own effort he put into reaching his maximum development and growth.

The student should not come out of college being a passive spectator of what is happening around and to him. He should have a good understanding of his political, social, economic and biological environments, and be prepared to participate in an enlightened way in the life of his community, state and nation. When the educational topics are relevant to him, he will respond with much more enthusiasm and with more participation in his own educational development. Therefore, the student should not be so manipulated by authoritarian control that his needs, wants and desires are ignored. This does not mean either that he should dominate or control all that he is taught.

Social Influences on the Curriculum

It has been shrewdly observed that the school always educates students, but it does so in a social situation at a particular time in a particular society and at a particular period in its development or state. Since education prepares young people to live and to make a living in association with other members of the social group, education must be looked upon as a social undertaking. Since every society has its own culture, we can recognize several cultural bases for the curriculum.

Teachers are members of society and participate in it as citizens, workers or parents. They are arbiters of the culture as well as directors of the educational activities of students. They usually have been thoroughly acculturated to the group for whom the curriculum is planned, and, therefore, are concerned with what the social group (be it national, ethnic, economic, religious, or other kinds of social groupings) thinks has been good for the society and ought to be conserved by including it in the education of students.

The schools educate students to live in the present society. Because society does not have a static culture, teachers must reexamine current problems and be willing to explore the possibilities for the near and distant future with students so that they will be prepared for enlightened living under circumstances not yet experienced by either the teacher or the student.

The culture influences the development and personality of the student and, therefore, determines what he will consider relevant in his education, and indeed, what is relevant. The enlightenment of understanding may be necessary to determine whether he has the perception of what is apparently relevant and what is actually relevant. Teachers can be the mediating link between these two conditions. In the end the relative importance of the knowledge, concepts, and understandings to be learned are determined by the culture, that is, by the society. Therefore, the curriculum planning must take into account the social as well as the natural motivation of students.

GUIDES FOR CURRICULUM PLANNING

Just as the student and society are determinants of the curriculum, other structures provide guidelines because they are part of the educative process. Two fundamental determinants of the educative process are the social group which has established the school and the learners that attend it. The functions, aims and purposes of the school as well as knowledge and theories of learning form important guides for curriculum planning.

Relation of Functions, Aims and Purposes to Curriculum Planning

When one examines the jobs the school must do, one is drawn to the view that teaching is its most important function. This is a rather general description which is a composite of the aims, objectives or goals which the school sets out to achieve. The purposes include both the functions and the aims.

An aim of the school may be to oversee the objective of developing the intellectual capacities of its student. The aim then has a desired outcome.

A function (or duty) may be to provide good quality educations to all of the students admitted. A purpose could then be to carry out an intention, such as making it possible for each student to develop his potentialities and talents to their fullest extent at his age.

An important statement of the functions of schools in America, if for no other reason than that it has survived so long, but actually important because it does reflect the function of the school in American society, was made by Charles A. Beard of the Educational Policies Commission of the National Education Association (1937). It says, in part:

> "The primary business of education in effecting the promises of American democracy, is to guard, cherish, advance, and make available in the life of coming generations the funded and growing wisdom, knowledge, and aspirations of the race. This involves the dissemination of knowledge, the liberation of minds, the development of skills, the promotion of free inquiries, the encouragement of the creative or inventive spirit, and the establishment of wholesome attitudes toward order and change . . ." (Educational Policies Commission, The Unique Function of Education in American Democracy, Washington, D. C. NEA, 1937 pp. 77-78)

The ultimate aim of the schools in the United States has been codified by various groups.

The Education Policies Commission, NEA, 1938, also felt that,

> "The general end of education in America at the present time is the fullest possible development of the individual within the framework of our present industrialized democratic society."

A group of educational reformers in more recent years have taken the position that:

> "The over-riding responsibility of the school, the responsibility it cannot shirk without disaster and may not sacrifice to any other aim however worthy, is its responsibility for providing intellectual training." (Arthur E. Bestor, The Restoration of Learning, N. Y. Random House, Inc., 1955 p. 33)

John W. Gardner (1961), President of the Carnegie Foundation for Advancement of Teaching, wrote that the American people should accept as an all-encompassing goal:

> "The furtherance of individual growth and learning at every age, in every significant situation, in every conceivable way." John W. Gardner, Excellence, N. Y., Harper & Rowe, Publisher, Inc., 1961 pp. 142-143)

Saylor and Alexander (1966) believe that:

> "In America, in the latter part of the twentieth century, the basic all pervasive aim of the schools is the fullest possible development in socially approved directions of each individual."

Phrases such as "attitudes toward order and change," "in socially-approved directions," "within the framework of our present industrialized society," place limitations on the "maximum development" contained in some of these statements.

On the positive side they recognize that the school is established by social groups for developing students toward the ideal social group member and not toward the opposite, that is, an anti-social group member or criminal. Other interpretations might be that these phrases tend to say that the school teaches students to accept the status quo for social sub-groups. The former interpretation seems more in line with the altruistic ethics of most leading American educators; the latter appears to be a political fact.

The Institute for Services to Education seeks to help colleges carry out their aim, function and purpose of providing the highest development of the individual student so that he will be the most productive as a member of our social and cultural group.

The Use of Knowledge in Curriculum Planning

It is self-evident that curricula for both the major and the course has a content. That is, students read printed and written material, look at pictures and analyze them, work with models and model systems, view demonstrations, films, pictures and displays, discuss topics, give reports and expound ideas, solve problems, make things, write about a variety of things, talk with their teachers and fellow students about things and ideas, and engage in other types of activities that result in learning of some kind--knowledge, attitudes, skills, behavioral patterns, or ideals aimed toward desired outcomes. All curricula, then, have content. The content is the planned information which will be the basis of the knowledge to be gained by students. Information and its mentally stored form, knowledge, then are as important a determinant of the curriculum as are learners and the society. This gives it a definite place in the curriculum because:

> Knowledge is essential for rational action. Decisions can be no better than the information upon which they are based.
>
> Man has a thirst for knowledge because man is by nature curious about his real and potential environment.
>
> Knowledge begets knowledge.
>
> Knowledge gives meaning to life itself.
>
> The welfare and progress of a people depends upon the rational action of its members.

Organizing Knowledge for Teaching

All of our sensory experiences are recorded. Much of it, however, is relegated to the subconscious. When information is received in the brain, it passes through circuits for discriminating (probably by impulse frequency) and switching so that these impulses are interpreted and classified as facts, data, observations, sensations, perceptions, and sensibilities. These constitute the basic elements from which knowledge is derived. This classification operation involves processes which form the basic rules or definitions for the determination of what falls within or without unique domains of knowledge.

Neisser (1966) has recently reviewed theoretical considerations in the cognitive approach to memory and thought. The concept of memory is associated by psychologists with traces, ideas, associations, schemata, clusters, habit-family, hierarchies and response strengths.

Perhaps the simplest and longest-standing accounts of memory were formulated by the English empirical philosophers, Hobbs, Hume, J. S. Mill and Locke--who assumed that one retains slightly faded copies of sensory experiences lying dormant in the brain cells. These are associated in time and are called up by association with other experiential traces, one or a few at a time. This view is no longer acceptable to most psychologists. However, these ideas have a long history in psychology and Neisser considers them to constitute Reappearance Hypothesis, since it implies that the same memory or other cognitive structures can disappear and be aroused over and over again. What is natural, on the contrary, is not to recall exactly but with variations adapted to the interests and values of the recaller at the time.

The Utilization Hypothesis emphasizes the use of traces of prior processes of construction (thought, recall, attention and perception). They are not stored copies that reappear but rather images constructed of bits stored in memory. It may be likened to bones of an incomplete dinosaur skeleton (or even a modern animal skeleton) which becomes a framework for reconstructing the shape of the animal. However, the finished reconstruction need not contain the bones. They are the structure that created and supported the living animal and give directions for its reconstruction to the animal morphologist. Cognitive structures (knowledge) play an important part in further learning and remembering and are frequently called "schemata."

In the cognitive approach to memory and thought, recall and problem-solving are constructive acts based upon information remaining from earlier acts. The use of that information depends upon its relation to the organization of the previous acts. This suggests that the higher mental processes are closely related to skilled motor behavior. For example, the ability to describe an experience through speech or writing is impaired if one is not a careful observer, "organizing" the various sensory inputs about the experience. The vividness of recall is enhanced by the number of different types of sensory inputs (seeing, hearing, feeling, etc.) perceived during the experience. Similarly, the way one plays tennis, or other games, where decisions about the stroke, placement of the ball, etc., have to be made in relation to conditions at the moment, depends upon previous experience recorded in memory.

There are a number of mechanisms which might carry out such tasks. It is hard to imagine one, however, that does not distinguish between a memory in which thelists are stored, and a processor which somehow makes use of it. The notion of a separate processor or executive is only indirectly admitted by classical psychological theories as "the higher mental processes," *e.g.*, Freud's "ego," "superego" and "censorship" (although he was more interested in what they suppressed instead of what they produced). The concept of mind is closely related to the executive. A model for these ideas is found in many computers. The computer program consists largely of calling on independent parts or subroutines, so that the program may read like the one on page 1-20.

Here the command CALL shifts control to the subroutine named, and RETURN sends control back to the executive or main program. It involves an executive decision about the value of the mean and determines what to do next with it.

Neisser is led to the notion of an executive by Bartlett's analogy between thought and purposeful action. Thought is certainly random most of the time rather than directed toward purposeful goals. It is true that "I" may construct an image during a train of thought but more often the image "just comes" as if "I," at least, had not constructed it. The idea of "logical" or "rational" suggests that each idea, image or action is sensibly related to the preceding one, making its appearance only as necessary for achieving the aimed-for goal.

Parallel programs, on the other hand, carry out many activities simultaneously, or at least independently. This is the chief characteristic of "primary processing" as it appears in dreams, "slips of the tongue," "free association," and many other types of disorder.

	FØRTRAN PRØGRAM	INTERPRETATION
	DIMENSION A (10)	Set aside 10 paces in memory (storage) location A (The computer will find it.)
1	DØ 2 (I), I=1,10	Do the steps to 2 ten times.
2	READ A(I)	Read the next number and put into storage at A.
3	CALL MEAN	Transfer control to Subroutine MEAN
	IF (MEAN) 6,6,4	Decision. If the mean is negative or zero, go to 6; if positive, go to 4.
4	PRINT N, MEAN	
	GØ TØ 1	
6	STØP	Stop operations.
	END	Terminate the program.
	SUBRØUTINE MEAN	
	N = 0.	Initialize. Return the register to 0.
	SUMX = 0.	Initialize. Return the register to 0.
101	DØ 103, I = 1, 10	Repeat steps to 103 ten times.
102	A(I)	Take the next number from storage in Dimension A
	N = N + 1.	Count the number of items by adding 1 each time a number passes here.
103	SUMX = SUMX + A(I)	Add the number X to the previous sum
	MEAN = SUMX/N	After all numbers have been added, divide by the number of items to get the mean.
104	RETURN	Transfer control back to the main program and make computations available to it.
	END	

What one sees in this example is that at address 3, control is transferred to the Subroutine MEAN, where the numbers are counted, added and the mean derived. The subroutine can even be in a different computer. In effect, the executive (main program) does not see the operations involved in getting the mean, it only asks for and receives the number of items (N) and the mean from the subroutine.

At address 4 the computation is used--printed or otherwise recorded. The direction GØ TØ 1 causes the main program to be repeated until there are no more numbers (mean = 0). Then the IF statement sends the operations to termination.

This kind of multiple processing goes on in dreams, schizophrenia, etc., but it is also normal for many thoughts (hundreds? of them) to come and go even when we are engaged primarily in purposeful activity. Their ability to interrupt the main train of thought, however, varies with the individual.

The constructive processes themselves never appear in consciousness, only their products. That is, we may only see the reconstructed dinosaur, not the bones. Thus, to construct something attentively is to "see" it clearly, i.e., to understand it. Such objects can then be remembered, and they can be reconstructed as visual images. They can also be represented in other modalities if an appropriate coding system exists. Particularly common is verbal recoding, which has the effect of re-storing relevant information in auditory memory where it is more easily available for later use.

Rational thought, then is "secondary" in the sense that it works with objects already formed mentally by a "primary" process. The associations in memory of knowledge-generating bits constitute the unique domains mentioned earlier and these domains make up the educational disciplines.

A discipline is an organized body of knowledge about a unique domain of things or events, for which basic rules are formulated and for which a recognized structure exists for organizing the body of knowledge, of incorporating new knowledge into the discipline, and for undertaking the discovery of knowledge essential to the extension, refinement, and calibration of the discipline. A discipline also has a history and a tradition that gives it status as a field of scholarly investigation and research and as a body of knowledge that continues to contribute to man's increasing control over his universe.

These structures are of value in organizing the content of the curriculum because:

Structure facilitates the use of knowledge.

Structure provides for better mastery of a domain of experience (i.e., a discipline).

A knowledge of the structure of a discipline enables the individual to revise his understanding of a field as new facts and data become known or as old concepts and principles are shown to be inadequate or erroneous.

Structure enhances memory.

Structure facilitates the use of knowledge in new stimulus situations.

Structure is the basis for making discoveries of new knowledge appropriate to the domain.

Structure enables the curriculum worker to make the best selection of content for study in course.

Organized knowledge constitutes a powerful capacity for action.

Ways in Which Content May Be Organized for Class Work

Content is organized different ways for different purposes. It may be classified by subject, by life activities, by the needs, problems, interests and experiences of students, or by job analysis and job-performance.

Organizing Content by Subject

Philip H. Phenix (1964) has succinctly stated the essence of the discipline approach when he wrote:

> "The curriculum should consist entirely of knowledge which comes from the discipline(s) for the reason that the disciplines reveal knowledge in its teachable forms . . . Education should be conceived as a guided recapitulation of the processes of inquiry which gave rise to the fruitful bodies of organized knowledge comprising the established disciplines."

That is to say, the mature generation has experienced what is most useful and relevant and they should construct a curriculum that sees to it that the younger generation gets these jewels of wisdom, as by lectures.

Shortcomings of the discipline approach are that there may be a considerable gulf between mature adult experience and interpretation and the experiences, interpretations, and abilities of the student, so that it forbids much active participation by students in the development of what is taught. Also, the interests of students may go beyond a strict limitation of the subject (for example, Biology as such). The result is that learning is fragmented and segmented, and the range of learning experiences becomes limited.

Organizing Content by Needs, Problems, Interests and Experiences of Students

The organization of the **learning** experiences around the day to day wishes and interests of a student is called the student-centered approach. This approach is based on two important components of educational thought that pervaded progressive educational thinking during the second quarter of the 20th Century. These were the necessity for motivation based on interest, meaning, and significance, for efficient learning; and the responsibility of the school to educate all students for individual and group living in a democracy.

Deficiencies of the student-centered type of content organization include the fact that it is difficult to determine the needs, interests and problems of students. Definitive statements of the needs of human beings have never been formulated to the satisfaction of psychologists. This approach also minimizes the structure of knowledge, the methods of discovery, and the depth of understanding of subject matter. It, therefore, militates against an organized program of education.

The ISE Modified-Discipline Approach

The organization of knowledge by discipline fits well into the programming structures currently in use by American colleges. However, the transfer of information by lecture only, has been of lessened interest to students in recent years. The program of curriculum development undertaken, first with the Thirteen College Curriculum Program, and later with additional colleges, was to explore which topics were of greatest interest to students and to build programs around that interest. The courses that developed, however, also contained a good bit of what teachers and subject matter experts thought should also be included. For example, in the biology curriculum, teachers presented more than 90 topics for discussion, using a number of inductive approaches to their discussions. The topics of most interest to students were then identified and teachers and specialists provided topical continuity so that the product would reflect up-to-date information and rational completeness. This procedure varied in other disciplines, but in general, areas of student interest were sought and built upon.

The freedom to choose daily activities is limited by the need to cover at least the basic areas of the discipline. Freedom is present, but is probably greater in relationship to the central topics in courses such as English, Social Science and Mathematics. Here the courses have essentially adopted laboratory sessions in which students gain first-hand knowledge and experiences, for example, through chamber theatre (in English), street corner research (in social science) or in strategies (in mathematics). In the sciences the cost of laboratory equipment and supplies, and the scarcity and cost of suitable laboratory assistants, greatly limits the freedom of choice for first-hand experiences in the laboratory. This, therefore, places some restrictions on the learning of the host of non-verbal definitions in science, especially in biology.

Nevertheless, the opportunities for broader experiences in the science courses exist for the motivated student. Flexibility of sequences, the provision of alternate and additional exercises and related literary resources, plus the immediate feedback of the discussion session, all work together to liven up the strictly discipline approach to organizing class material, and at the same time tends to overcome the deficiencies of an approach based solely on the interest, needs and problems of students.

Organizing Content by Life Activities

Rousseau proposed that there is a best time to teach and to learn, and that is when there is some purpose in learning and the student is ready and willing to learn. Content organized by life activities is usually selected for utility. The learning experiences are, therefore, meaningful and significant to the student and that makes for efficiency in learning.

Shortcomings of the life activities structure are that the information becomes useless if anything changes, such as when a new technique, or a new machine or process is developed for doing a job. The other drawback is that schools are not organized to deal with this arrangement and there is much inertia for change.

Organization by Job Analysis

The last of these ways of organizing content, job analysis and job-performance, is the basis for vocational education and is closely related to the discipline approach in that it is didactic and utilitarian to the degree that it may be rendered useless if something changes.

Use of Learning Theory in Curriculum Planning

A primary function of the college is either to provide teaching in desired subjects for students, or to provide students with opportunities to participate in learning experiences. These should result in learning. We cannot tell much about the actual learning that goes on, but we can observe and measure the results of learning. These would include:

the acquisition of knowledge

the formation of concepts

modification of value systems toward the social good

modification of concepts of self

aspirations for new patterns of behavior, and

the improvement of aesthetic satisfactions with the beauties of nature and life.

If teachers and other curriculum planners, such as those in the ISE, are to be skillful in planning and guiding the development of the curriculum so that good experiences are had in order to get the above results, then they must have a thorough knowledge of the processes of behavioral change, or else their efforts may fall somewhat short of the objective. That is to say, good planning may not assure better learning, but poor planning or no planning will almost assuredly produce poor learning.

Robert Glaser (1962) identifies four basic aspects of teaching, viz:

1. Instructional goals
2. Entering behavior
3. Instructional procedures
4. Performance assessment (evaluation)

It is almost easy to forget that the purpose for which the student attends the college of his choice is to learn, and his success is largely due to the instructional procedures used. Sometimes so much emphasis is placed on what content should be in the course (a question too often answered with an overgenerous portion of information), and having the student remember it, that little attention gets paid to ways of teaching it. To be sure, research on teaching behavior (methods) show that there may not be much apparent difference in the amount of information stored. Other evaluations show that there are differences in the kind of product resulting from particular teaching styles. For example, in the ISE-sponsored groups of students at the several colleges consorting together for the purpose of curriculum improvement, a significantly higher proportion of ISE students seek and obtain leadership roles in student activities on their campuses.

Regardless of the state of the field, a good understanding of the principles of learning contribute significantly to the ability of the curriculum worker to plan learning activities what will be most effective in helping students attain the outcomes desired, that is:

adaptation of instructional methods and procedures to the interests needs, capacities, talents, and the maturity of individual students;

creation of desire among students to learn and to take more responsibility for their self-development;

planning instructional activities on the basis of how students learn;

selection of the most appropriate teaching methods and materials for the achievement of a specific course purpose or aim;

formulation of hypotheses and the formulation of corresponding experiments to test the effectiveness of teaching; and

understanding the forces that produce change in human behavior and use those forces with insight to produce the desired learning.

THEORIES OF LEARNING

Stimulus-Response Theories of Learning

The stimulus-response theories of learning include the more specific ones of connection, conditioning, stimulus-response, and behavior. It is the induction of such responses that include this group of theories among the inductive teaching and learning methods because the student is expected to respond to a stimulus (object) presented by the teacher.

Hilgard, Marquis and Kimble (1964) are representative of the psychologists that favor this method. They see three basic elements in learning--stimuli (S), responses (R), and the interaction between them (---). The wide acceptance of this viewpoint by psychologists rests on the fact that conditioning provides the clearest picture of how a response becomes associated with a stimulus and also provides the simplest form of learning. By observing it closely, one can uncover the secrets of the learning process.

The principal weaknesses of the S-R theories are a total lack of consideration, or at least an inadequate treatment of the place of knowing, insight, understanding, motivation, and the perceptions of self in learning. It also neglects the mechanistic and behavioristic concepts of human behavior and the inability to explain adequately many aspects of the commonplace observations of teachers about behavior in the classroom.

Functional Theories of Learning

Functionalism is based on S-R factors, but introduces other elements in the learning situation. Robert S. Woodworth is an exponent of this view along with Carr, Angell and Dewey. Woodworth, in his dyamic concept of behavior, emphasizes the learner's active role (motivation) in determining the nature and course of his behavior and consequently of what is learned. He inserts O-for-"organism" in the equation S--O--R. This postulates "situation-set" and "goal-set." To a functionalist behavior is primarily a matter of problem-solving. An individual, in the course of his on-going activity, is confronted with a block or obstacle to further activity which he must solve before he continues. Thus, the learning process is primarily a matter of the discovery of the adequte response to a problem situation and the fixation of the satisfying situation-relationship. For the functionalists, activity is the basic ingredient of a psychology of learning. Dewey adopted this concept as the basis for a philosophy of education that has dominated forward-looking educational theory and practice since the 1920s.

Cognitive Theories of Learning

The cognitive theories of learning include what are known as field Gestalt, sign learning, cognitive, and classical Gestalt. All of these viewpoints give greater emphasis to the role of knowing than do the stimulus-response theories. Learning according to this group of psychologists, results from a problem situation. A person has a tension, a disequilibrium, in an unresolved situation which has significance for him in terms of his own personal situation. Insight is dependent on four factors:

the intellectual capacity of the student

the past experience of the learner

the situational arrangement itself

some trial-and-error behavior that contributes to the development of insight.

CHARACTERISTICS OF A GOOD CURRICULUM

1. A good curriculum is systematically planned and evaluated.

   A definite organization is responsible for coordinating, planning and evaluation. (ISE does this for its consortia).

   Ways of working utilize the contributions of all concerned.

2. A good curriculum reflects adequately the aims of the college (as a component of the college program) and of the course. (See aims of the course.)

   Each learning opportunity is planned with reference to the attaining of one or more goals.

3. A good curriculum maintains balance among the objectives sought.

   It gives emphasis to each goal according to its relative importance to students and curriculum workers.

   The total plan provides opportunities in each of the basic areas of the course.

4. A good curriculum promotes continuity of experience.

   It is not only concerned with the internal content of the course, but also the relationships of that content with other areas of knowledge. Provisions, thus, are made for smooth transition and achievement of the student.

   Cooperative planning and teaching provide for exchange of information about the characteristics of students and their learning experiences.

5. A good curriculum arranges teaching and learning opportunities flexibly adapting to particular situations and individuals.

   Curriculum guides encourage teachers to make their own plans for specific learning situations.

   Cooperative teaching and planning utilize many opportunities as they arise to share learning resources and special talents.

   Time allotments and schedules are modified as the need justifies. A program is expected, but it is also expected to allow for flexible rearrangements due to the interests of the class.

   Careful attention is given to the interests of students, and where possible, they may participate in the planning of some specific learning activities.

6. A good curriculum utilizes the most effective learning experiences and resources available.

   The experience of students are developed so that they see purpose, meaning and significance in each activity.

   Needed, available resources are utilized at the time they are relevant and helpful. This refers to individuals as well as classes.

   Teachers discriminate wisely between those activities which may be carried out with direction and those which are less supervised. This is particularly seen in the dichotomy between exercises (for the acquisition of skills) and experiments (for obtaining and evaluating information).

7. A good curriculum makes provision for the maximum development of the student.

   The curriculum promotes individual development rather than conformity to some hypothetical standard (especially the teacher's own past experience).

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CHAPTER 2--TEACHER SELF-CONCEPTS AND TEACHING STYLES

TEACHER ROLES RELATED TO TEACHING METHOD

The term role, as used in this discussion, refers simply to a pattern of behavior shared by a group of teachers. It is identifiable and generally believed to be related to the learning process.

A teaching method is also teacher behavior in the classroom related to learning, so that the role and the method are interdependent upon teacher behavior, and in fact the terms are used interchangeably.

Sometimes a role of the teacher lies outside of the classroom, since they like all other people have a variety of roles, such as being a parent, church member, club member, citizen, or member of a political party.

Obviously, teacher roles can be classified in a number of ways. Kinney (1952) and Fishburn (1955) have used the following classes based upon six common areas of teacher activity:

Director of learning,

Guidance and counseling person,

Mediator of the culture,

Member of the school community,

Liaison between the school and community,

Member of the teaching profession,

and we would add,

Information specialist such as zoologist, botanist or physiologist.

In their study, the above researchers asked teachers and administrators to rank these roles in the order of importance. Quite different orders were indicated by the two groups, indicating that teachers and administrators either view the roles of the teacher differently or they interpret the meanings of the roles differently.

PATTERNS OF TEACHER BEHAVIOR (PATTERNS OF TEACHING METHODS)

Patterns of teacher behavior, that is, patterns of teaching method, may be identified in a variety of ways. The classroom methods of an actual teacher may be described, if one can find a teacher that approaches the ideal model.

Or, one can construct and describe the behavior (teaching pattern) of an hypothetical teacher as being either "typical" or a "model" of the projected type. During the 1930's, when the Progressive Education Association was influential, it was not uncommon to contrast an "authoritarian" teacher, who used that position of power to direct students, with the more "permissive" type of teacher that delegated most decisions, if not all of them, to the students in their democratically-run classrooms. However, in more recent years, the concepts put forth by Carl Rogers, of "directive" and "non-directive" methods in teaching, have been more popular. All of these patterns are based mainly on sociological interpretations, but they have also helped to clarify thinking about teacher behavior and the complexity of the problem.

Most contemporary teaching methods are not based to any great extent upon the results of scientific research. Wallen and Travers (1963) offer the following as the origins of contemporary teaching methods or patterns of teaching behavior:

> Patterns derived from teaching traditions where the teacher teaches as he was taught.
>
> Patterns derived from social learnings in the teacher's background as when a teacher tries to develop middle-class ideology by reinforcing that kind of behavior.
>
> Patterns derived from philosophical traditions, such as those of Rousseau or Dewey.
>
> Patterns generated by the teacher's own needs, as when one lectures because he needs to be self-assertive.

A teaching style which is highly permissive would be favored by persons with either a high control need or a low control need. Where a high degree of control is desired, it represents a breakdown of intellectual and social control over the class leading to confusion and disorder. The latter condition (a low control need) reflects a high degree of emotional security with regard to the class.

Gordon (1955) studied the relationships that may exist between these patterns of teacher behavior and the environment in which learning occurs. The study was undertaken in a suburban high school with a student population derived from all socio-economic levels. The pattern of behavior of the typical teacher there was largely derived from the fact that he was an intermediary between the student and principal in the authority system. The chief threat came from student interaction with authority, such as talking, whispering, and horseplay. The teacher tolerated such behavior up to the point where it became a challenge to his authority (but not to learning) and then took some action to suppress it. Over a three-year period referrals to the principal declined, because it was rumored that the principal graded teachers in part, on the basis of the number of such referrals. It was clear that the success of such authority figures depended upon the degree to which the principal supported authoritarian positions.

Patterns Derived from Research on Learning

One may ask why have the behavioral sciences been so lacking in the design of teaching strategies? A simple answer is not forthcoming, but some of importance are:

1. There has been a tendency to choose elements from the behavioral sciences that appear to fit with the philosophical traditions of teacher education. The unit of behavior, emphasized in Gestalt psychology, closely parallels the unity both in man and nature which Froebel emphasized, although Gestalt psychology has little to say about the design of teaching methods.

2. Schools of education have tended to close their doors to persons who are specialists if they do not hold teaching certificates.

Few attempts have been made to design a teaching method. Carleton Washburne developed the Winnetka Plan (1932), Olson (1959) in Child Development also advocated a teaching plan based on a broad review of current psychological research. A. D. Woodruff in his Fundamental Concepts of Teaching (1959) designed a teaching model. He lists a set of learning principles together with the behavior the teacher should exhibit in order to carry out the principles. Many educational psychologists agree that a teaching method cannot be designed in terms of a set of laws of learning alone. It must also include a set of laws about teacher behavior. However, such generalizations have not yet been derived from the research regarding teaching.

The Teaching Method in ISE Courses

The fact is that inductive teaching methods, involving discussion sessions, call for a particular kind of personality, or a shift in the valuing systems held by traditional teachers. Just as a decrease in authoritarian behavior, in the study related above, resulted from the position of the administrator toward that attitude, teachers who accept appointments to teach the ISE courses can be assured that the desired stance favors less authoritarian positions with regard to many aspects of teacher-student interaction.

Perhaps this is the most difficult change to make. The teacher who lectures has a certain distinguished authority in his statements (even when they are in error). He will seldom be seriously challenged because students want to pass and they don't think they will if the teacher is angry with them. Also, there is a practice of not being checked upon by knowledgeable persons from within the college structure. This lack of scholastic accountability (behind the screen falsely-labelled academic freedom) has given license to many teachers to dispense out-dated or wrongly-interpreted information. To challenge the accuracy or the amount of information a teacher actually possesses has been the basis of anger, sulking and the desire to squash the challenge like an undesirable bug, instead of a constructive endeavor to improve the content and quality of the presentations.

The bases of these feelings is false pride. Declarations of superior attainment frequently are made to compensate for a realization of scanty or outdated information and poor teaching. Placing the blame on the inability of the student rather than the quality of the teaching and examination is common.

The role of being a director of learning changes from the picture of a teacher to one more related to that of a guidance and counseling person. Actually, the discussion leader is just as entitled to, and obtains, the respect of students as a well-informed person just as easily as would a lecturer. Being a discussion leader demands that the false pride of some lecturers be abandoned. It means being well-prepared, formally and informally, in the topic for discussion and in related topics. It means the teacher has to be an active learner (and not take the position that he doesn't need to learn more because he knows more than the student, at least a little more) and that he has to read more than just the assignments made to students. This means a high degree of confidence in one's preparation that is described as emotional security. This makes possible the low or moderate anxiety situation in which discussion can occur. There is no need to control extraneous activity because if one has the attention of all students they won't be surreptitiously reading comic books ensconsed between the pages of the text, holding private conversations on other subjects, and the like. In fact, a good discussion involves a lot of student-to-student exchange in addition to the teacher-student exchanges. The objectives of a discussion session and techniques of leading discussions are taken up in Chapter 3.

The curriculum programs have counselors who try to help the student overcome most of his personality, study and financial problems. In addition to the counselor's services the teacher performs some counselling and guidance functions, too. Office hours are established so that students may extend their understanding, or simply become better acquainted with the teacher. The small size of the class helps to overcome the depersonalization of the large lecture section. The conference period can help individualize instruction even more. In addition to course content, there are advisements about further courses, interrelationships with courses in other disciplines, and career opportunities as a professional biologist, teacher, research technician, etc.

The better acquaintance of the teacher and students does not mean that the dignity and courtesy extended college teachers is abandoned. It only means that teachers will not conceal their inadequacies behind a formal facade. Any deficiencies should be temporary. They should be overcome in short order or else, if it is an informational problem, it should be jointly explored by the teacher with a few students or with the class.

IN THE LIBERAL TRADITION OF EDUCATIONAL THEORY AND METHODS.

Education may be described as the process through which an individual has his attitudes, personality and behavior developed. It consists of a series of experiences, either planned or unplanned, that occur in an individual's life. All experiences are educational to the intelligent being, whether they result in good or bad effects upon him, and teach him to cope more effectively with similar experiences pertinent to his life goals.

While every person is educated through his own experience, society does not leave the education of the individual entirely to chance. To accomplish this end, the student is subjected to the social process in a special environment called the school. In establishing schools, society provides opportunities for the student to live through the experiences which will develop his ability to live in his kind of society. Through the school, society transmits information about the knowledge, the skills, and the emotional organization approved by that society. Society, therefore, takes this means - the school - of realizing the kind of life which it regards as the best.

Educational Theories

The theories of great educators in Western civilization constitute a tradition which profoundly influences current answers to the questions: What should be taught?, who should be taught?, and how should they be taught? These questions were considered by Socrates in The Socratic Method - where he introduced a method of questioning and analysis that is still employed today in secondary and higher education. Plato describes, in his Republic and Laws, three classes in society - those that produce, those that fight, and those that govern. Higher education in his scheme was for the philosopher-ruler. Plato emphasized "education in virtue from youth upwards, which makes a man eagerly pursue the ideal perfection of citizenship, and teaches him how rightly to rule and obey." The process reached its high point in the study of dialectic (the rules and methods of reasoning and analysis).

During the rise of the Roman Empire, Quintilian considered the orator to be the manager of affairs. He believed that the man who acts in a real civic capacity, who had talents for the management of public and private concerns, who could govern cities by his counsels, maintain them by his laws, and raise the quality of life by his judgments could be none but the orator. In his view, the student would be entrusted to good masters from the first, who would not whip him but would appeal to his interest and thus bring out the best that was in him.

Ignatius Loyola was interested in training devout and capable religious missionaries. His aim was to lead the student into the service and love of God and the practice of virtue. One of his greatest contributions was his insistence that those entrusted with the delicate task of educating youth should be chosen with exacting discrimination.

Johann Amos Comenius regarded the schools of his time as "terrors for boys and shambles for their intellects." By following the principle of order he would teach all those subjects which make a man wise, virtuous and pious. He would conduct school "without blows, rigor or compulsion, as gently and pleasantly as possible." The student would find instruction adapted to individual differences and would learn to know and to investigate things themselves. The major writing of this 17th Century Czech, the Didactica Magna, was the first complete and systematic treatise on education derived from a psychological understanding of the learning process. The Didactica stressed the importance of sensory knowledge and the growth of learning from the known to the unknown. Comenius sought knowledge to expand experience, and in that respect could still be considered a modern educator.

In the early part of the 18th century, Jean Jacques Rousseau began to speak out against the educational methods in the schools of his time and exercised a strong influence not only on European schools, but also those in America in the following century. He advocated a kind of "naturalism" in education, asserting that the best time to teach or learn was when there was some life situation to which the new knowledge would be relevant. Rousseau's view was that a student must learn by discovery and by doing, not by being told.

Johann Pestalozzi disliked the memorizing kind of school and the harsh discipline in the schools of his time. He substituted pleasant learning activities derived from the naturalism of Rousseau's approach of educational planning, for he too believed that the school should be an enjoyable place. He stressed the "observations" approach which led to "object teaching" in a later period. Pestalozzi, and his followers, Johann Herbart and Frederick Froebel, had a decided effect upon American education. Herbart attempted to systematize each lesson. He drew up a statement of steps which later became known as the "five formal steps in instruction." These were preparation, presentation, comparison and abstraction, generalization and application. His system of psychology was founded upon a concept that the mind was developed through contact with the outside world but that the understanding of each new experience depended upon its relation to the individual's past experiences. Part of the teacher's task, therefore, he believed, was to relate each new teaching to the previous knowledge of the student. However, Froebel, probably best remembered as the father of the kindergarten, did work with older youth, also. In contrast with Rousseau's concept of a highly individualized education, he favored the participation of students in groups and he idealized a school without textbooks or prearranged intellectual tasks - that is, a school that was flexible.

Methods

The scientific study of educational methods gained impetus from the activities of the Herbartian Society, formed in 1892. It sought better methods than the age-old formula of "teach, recite, test" which many teachers were still then using on all levels of instruction. Through this society Herbart's five steps were refined and popularized. However, the formality of the five steps stirred up vigorous protests from the followers of Rousseau, Pestalozzi and Froebel. Although these latter groups also advocated getting away from the "teach, recite, test" pattern, they insisted that the educational process should provide the students with naturalness, creative and productive activity, and self-expression. Despite the spread of these ideas, however, the bulk of teaching was centered about the recitation method until the late 1920s.

V. T. Thayler ushered in another phase of the struggle for better methods with his book, The Passing of the Recitation (1928). He contended, with some justification, that the recitation method was out of harmony with what should be the objectives of modern education. He pointed out that the results of the then widespread research into educational methods were beginning to show that methods were instruments to be used by teachers and learners to achieve clearly-formulated, educationally desirable purposes, and that the method used should be an appropriate means to achieve the desired goal. This point of view led to a reconsideration of several methods developed during the first quarter of the 20th century. Among these were the "Project Method" which emphasized concrete, tangible, practical, learning-by-doing activities. The "Socialized Recitation" method which came into prominence because it afforded an opportunity to organize learning groups as social units in which common purposes and responsibilities were shared. The "Laboratory Plan," as developed by Helen Parkhurst and Carleton Washburne, also gained widespread attention. Features of this method were that all classrooms should become workrooms of appropriate type, that is, not limited to desks, that the involvement of the student in the class activity was of prime importance, that each student progressed at his own progress. Radically revised teaching methods were developed to carry out these principles. These included the "Contract Plan." This was essentially an attempt to individualize instruction by means of individualized assignments, thus making the student less dependent upon the teacher and group instructional methods.

Two other movements stemmed largely from the contributions of John Dewey earlier in the century. These were the activity movement and the unit plan of teaching and learning. All levels of instruction, including the institutions of higher education, appear to be influenced by these two newer modes of organizing learning situations. There is support for the idea that these two modes, however, are but phases of a single process for, in order to learn, a student must be active, and therefore, "involved," and he must have a clear-cut goal. Both the goal or goals and the activities needed to achieve them may be set up in the form of a unit of activity.

These exerpts from J. G. Ummstattd help to define the essential elements of a unit: "The central fact of the unit idea is that content should be studied as meaningful wholes rather than as isolated or unrelated lessons or bits . . . Of as much significance as the arrangement of the content in significant wholes is the manner of attack and study. The mode of approach . . . is closely associated with the unit method. It involves several distinct steps . . . which parallel the rational operation of the human mind." Another aspect of the unit idea relates to the length of the unit or the meaningful whole of the content. "Length is conditioned entirely by the given situation. The maturity of the student is one factor which should be considered in determining the amount of detail to be included in a given unit or the length of time devoted to it."

In line with relating classroom activities to real-life situations, sometimes referred to as "relevance," now common in many classrooms, has come the realizations that what a student learns is not to be completely separated from how he learns. These two things, content and method, tend to merge when it is recognized that having a goal sets the stage for providing the material needed - that is, the subject matter and establishing the means for using it (or the method). This fact, along with the recognition of the importance of the student as an individual, has increased the emphasis upon flexibility of procedures that takes into account the individual as well as group needs and interests of students.

A GLOSSARY OF TERMS

Because some terms may be used to describe conditions or situations in ways not ordinarily understood, we would like to set forth their meanings as used in these essays.

Didactic is from the Greek (*didactikos*) meaning inclined to teach. It has come to mean inclined to teach too much, more in the sense of lecturing to someone. We use this term in another widely accepted interpretation meaning to teach by precept and example, that is, to show the student how to do things. For example, the use of the microscope is taught didactically because to let students learn to use it by discovery would take a long time and probably result in damage to an expensive instrument.

Inductive from the Latin *inductare*, to lead in, has several meanings. In physics and electricity one speaks of inducing a current in a coil. In philosophy one speaks of inductive reasoning whereby one takes experimental observations of other facts, and by inductive reasoning arrives at generalizations. Its use as a description of education method comes from physiology where one might induce a response by applying a stimulus. In the present context inductive teaching methods refer to those which induce a response in the student, as contrasted with didactic teaching methods.

Object-centered refers to an approach which centers the attention of students on something (an object) worthy of consideration or study. This is the usual thing in the sciences and is distinguished from centering upon authoritarian interpretations and opinions of an individual about such objects.

Student-centered refers to an approach to teaching where the student decides what he wished to study during any particular period. In practice he is given several things as alternative activities during a class period and he may choose one, several or none of them. If the student is not interested in any provided activity he is not taught. This is contrasted with object-centered approaches where the whole class will consider the same kinds of interest, thereby *motivating* the student to study or consider the object or ideas about it further.

Sequential discussion leads the students from one fact to another until, by inductive reasoning, they are brought to generalizations about biological (and other natural) phenomena and perhaps some type of individual or class activity.

Integrative discussions bring information from several segments of knowledge to bear in understanding particular aspects of a question. Both sequential and integrative considerations bring into play a view of William James that new information must harmonize with what is known in order for it to be considered "true" by reasoning individuals.

Open-ended discussions usually begin with the consideration of possible solutions to a problem. This does not lead to the solution of the problem and therefore is "open-ended." In order to arrive at a satisfactory solution one must resort to either integrative or sequential reasoning in the discussion.

When "open-ended" is now used in describing laboratory activities, it usually means that the answers are not given and the activity, while partially answering the starting hypothesis, should also generate a continuation hypothesis for the student, that is, it does not lead to a complete solution to theoriginal problem. Therefore, another experiment is needed to finish answering the question.

Traditional teaching methods usually means being didactic, that is, using the "teach, recite, test" approach to scholarship. Of course, there is as much tradition for the inductive methods as for the didactic ones. The validity of using the term "traditional" for didactic methods is that didactic methods are overwhelmingly used in college teaching. Inductive methods have been more usual in elementary and secondary schools and therefore are innovative in college classrooms even though they represent a long tradition in teaching theory and method.

Laboratory-centered course is not clearly defined. It may refer to a course where the major evaluation (grade) comes from the laboratory activity. It is sometimes used in the sense that the laboratory precedes the discussion about the activity and its results. In this case it becomes the "object," or a problem raised in the minds of students during a laboratory period but left unanswered may become the topic for an open-ended discussion. Following the discussion one or more laboratory periods should be spent on other experiments which sequentially or integratively provide conclusions to the original problem.

WHAT ACTIVATES STUDENTS?

Edward J. Murray in his book Motivation and Emotion (1964) describes the human being as a "marvelous organism capable of perceiving events, making complex judgments, recalling information, solving problems, and putting a plan into action. Yet, this intricate apparatus can be used for a variety of ends - to plan for war as well as to explore outer space, to humiliate another person as well as to comfort the sick, to achieve recognition, dominance or friendship. The uses to which a person puts his human capabilities depends on his motivation - his desires, wishes, wants, needs, yearnings, hungers, loves, hates, and fears." We may draw applicable examples from among types of students at predominantly Black colleges. John is the son of a poor farmer. His folks have always wished that their children would be better off economically than they were and, therefore, they have looked forward to John's entrance into a profession such as teaching or the ministry. They have from his early childhood encouraged him and rewarded him for doing well in school. He, therefore, set high standards for himself. Moreover, since he appreciated the fact that his mother took in washing to make the extra money to make up the difference between college costs and his scholarship, he nearly always made at least an A.

Susan was the daughter of a successful physician in a large southern city. Her life had been comfortable and pleasant, and she never really worried about the future. In college, she expected to gain the knowledge needed for the fuller appreciation of life and for the cultural enrichment of her future children. College would be the right place to look for the kind of young man on his way up that would meet with family approval. Susan, most usually, made a C and was satisfied with that level of performance.

Joe was the son of a successful contractor. He was a bright boy but did not share his father's dream that one day he would take over the business that had built up over the years. Joe wanted to be a physician but, primarily, he was determined to be successful at something else other than contracting. However, at examination time Joe would tense up, become over-anxious and do poorly on his tests. It seemed that he became more tense with each examination and did still more poorly. At the end of his Freshman year he was asked to withdraw because of his low academic average. Joe had a lot of D's and F's.

John was motivated to get high grades. Joe was motivated towards achievement but a competing emotional motive prevented his success. Many freshman students in Black colleges have Joe's problem of competing emotional problems. During the summer of 1968 the biology staff* stated their observations about students in the biology course. It said, in part, "Firstly, it is noted that a considerable number of the students involved are intelligent, but they lack proper motivation. Secondly, the students have not been sufficiently challenged to meet the norms of achievement, or, having been challenged, they have not elected to meet the norms; hence they are 'underachievers'. Thirdly, the factors producing failure to meet these norms are really not precisely known, notwithstanding the fact that there is considerable evidence which points to such factors as deprivation, lack of proper exposure, and lack of exemplary precedents. Fourthly, these negative factors are not remedial in the biology classroom or laboratory. Thus, the problem has come to be a matter of finding a way to overcome and negate these undesirable aspects in the teaching of biology."

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* Dr. Paul Brown, Chairman.

The study of motivation is relatively new so that there is no single generally-accepted idea about it. Instead, there are ideas which have been gleaned from philosophy and biology which have formed a group of competing notions, each with its followers. Cognitive theories involve one of the oldest views - that man is a rational being and, as such, has conscious desires and tries to find ways in which to fulfill them. These may be summed up in the old adage, "Where there's a will there's a way." Hedonistic theories center around the concept that man seeks pleasure and avoids pain. The use of hedonism here should not be construed as being the same as the ethical system where one purposely builds his life around the seeking of pleasure and the avoidance of pain, but instead as part of an attempt to explain why some people behave as they do. Both the cognitive and hedonistic theories are largely rejected by modern psychologists for explaining motivation. It was Charles Darwin who brought to the front the forerunners of the instinct theories. He felt that what he called "intelligent" actions were inherited. By the turn of the century the idea had been further developed, by William James and Sigmund Freud, as an important explanatory concept in psychology. McDougall listed eight such instincts in 1908 but by the mid-1920s the list had grown to more than 6,000, some of them frivolous and ridiculous, such as the instinct "to avoid eating apples in one's own orchard."

Drive theories dominate the acceptable theories today. One reason for this is that drives were introduced one at a time, on the basis of careful experimentation and, therefore, have specific operational definitions. They can be experimentally developed and experimentally measured. The logic of the drive theory was reinforced by the introduction of the concept of homeostasis, or the steady state. This idea had its beginnings with Dr. Claude Bernard in the 19th century but was brought to its present interpretations by Schoenheimer (1923) and Walter B. Cannon (1932). They suggested that when conditions in the body deviate from the "normal," psychological drives are one way the body seeks to re-establish normalcy, and thus relieve "tension." Some questions still remain about drive theory, such as, are all incentives and rewards based on homeostatic tension and tension-reduction, and are all social motives based on the primary physiological drives such as sex, hunger and pain?

Although there is division of opinion as to the causes of motivation there is substantial agreement as to what is meant by the term. A motive is usually divided into two components: Drives refer to the internal processes that push a person into action. The stimulus for the drive may be external but the drive itself is internal. The termination of the drive is obtained by the gaining of a reward. A goal or reward may involve an external object like a grade, but the drive-terminating process itself is internal.

A body of experimental evidence has now accumulated which suggests that increasing a drive up to a certain point increases learning behavior but extreme degrees of drive may actually result in a deterioration of learning rate. Motivation also affects memory. Tension and emotion greatly modify perception so that pleasant things are generally more easily remembered. So the information one has at any particular time has been discriminatingly filtered through his motivation and attitude neural pathways.

Motivation also plays an important part in how one uses information in the symbolic processes of creative thinking, problem-solving, and the like.

Problem-solving should be differentiated from the formation of simple habits in that an interrelationship between the parts of a problem must be understood in order to arrive at a solution just as a correct diagnosis must precede adequate treatment and cure. On the other hand, the ability to solve both structured and unstructured problems seems to involve the acquiring of discrete habits in a unique way so as to meet the requirements of a situation. Such behavior is sometimes said to be the highest form of human thought and it is the kind involved in the work of scientists, engineers, business innovators, physicians, and others.

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CHAPTER 3--LEADING AND PARTICIPATING IN A DISCUSSION

When a teacher learns that in this course discussions largely replace lectures, many possibilities and apprehensions come to mind. Perhaps the first response may be, "I'm not a discussion leader. If lectures are not absolutely prohibited, maybe I can get away with lecturing for awhile. If the students revolt, maybe I'll give the discussion a bit more of a try, but until then, well ......"

Another kind of reaction is, "I always was a little scared of lecturing to 200 students. Discussions with 25 or 35 students ought to be duck soup. When do I start?"

One teacher, in discussing the view of some teachers new to the method of discussion instead of lectures remarked that they thought a class of 90 students was too large with which to hold a discussion. Even though this was an experienced teacher with good discussion skills, she nonetheless felt a bit uncertain after the skepticism of her colleagues.

Other questions raise are typified by these:

"Why use discussions instead of lectures? We are already excellent lecturers and our students compete with the best from other schools in our league."

"What do you mean by discuss? I always stop and ask if there are any questions. They (students) seldom have any. They have a lot of faith in me as an outstanding teacher."

"I'm interested in participating in a quality educational program. Can student interest be better than my experience in selecting topics for the course?"

"How can discussion be as efficient as a lecture?"

Rarely one asks, "How can I become a good discussion leader? This approach is completely outside of my school experience."

WHY USE DISCUSSIONS INSTEAD OF LECTURES?

There are many topics for which a well-organized lecture might serve well to communicate a point of view or sequence of reasoning, or to impart some series of facts. The student may take notes or the teacher might provide them. The student is expected to avail himself of this "learning opportunity." Sometimes he may learn some facts. Frequently, he attends the lecture and considers it to be an indicator of what he should study and know in order to please the professor. He then does his "learning" on his own, that is, memorizes the teacher's facts and reasonings, fully aware that these facts will be asked for on an examination in the near future.

Since memorizing has constituted the bulk of the school experiences of most students, many of them have mastered some system of memorization.

Generally speaking, the well-ordered, conservative, non-imaginative student, who is highly anxious about successfully performing in the course will prefer lectures. He may not like them, but he understands the system (that is, the lecturer system) even if he doesn't understand the material he memorizes.

On the other hand, if he has studied before he comes to class for discussion, he can view the teacher, not as three feet above questioning, but as a consultant and coach who can help him understand the topic better. He may integrate the new ideas brought up with what he has found previously to be valid. Not every comment or question is a good one, but in the exchange, ideas for the improvement of his own concepts are generated. It is not just a matter of adding more information, but rather the idea of building better understanding of his information.

The teacher in this situation does not have the emotional security of having looked up every fact. The questions may lead him where he would not wish to go. To say the least, the situation requires the broadest preparation on the part of the teacher. He needs to read more widely than when preparing a lecture. He may need to give some critical examination to what he does read to determine its validity, appropriateness, and for the currentness of the information.

Another reason for our preference for discussion over lectures is the involvement of students as active participants in the teaching-learning process. Again, many students would prefer to be passive recipients of the thinking of the teacher. We feel, however, that discussion should be conducted in such a way as to make the student an active seeker of knowledge and a person having the self-assurance and ability to analyze so that he can ask questions about the material he doesn't understand.

WHAT DO WE MEAN BY "DISCUSSION?"

It is almost easier to define a discussion in terms of what it is not. Actually discussion occurs between interacting individuals in a group (two or more). That is to say, it is not a one-way situation. It is not unusual for teachers, and others, to lecture for a few minutes, then ask a question, expecting a particular answer--after which they go back to lecturing. That is not a discussion. A discussion is not an oral examination, nor is it a series of pronouncements on a subject. Flip "the coin" over and it is equally clear that if only students ask questions, then the teacher must lecture in answering them.

What one strives to achieve is an interacting group where some of the reserve and "stand-offishness" has been dissipated. Students, by having signed up for the course, admit a certain ignorance about the subject. Teachers, by their position, have a certain personal dignity to maintain. Even though they are encouraged to forget about that, the uncertainty about the kinds of information students will ask about may leave them apprehensive. Teachers need to be well-informed, but also willing to admit they may not recall every last detail at times. If, however, a teacher finds a topic brought up for discussion on which he does not feel well-informed, he may delay that discussion until the next time. But then, he should be prepared more elegantly than students would have expected. From that point, students may also be brought into an investigative activity in search of possible alternatives. This mutual trust and respect for the purity of the motives of students and teacher in the learning situation is an essential condition for effective leadership.

A discussion, when well-done, should be an intellectual exchange between teacher and students and between students themselves.

In all this, the teacher plays a leadership role, keeping the discussion from straying too often toward frivolous or peripheral issues.

HOW CAN A DISCUSSION BE AS EFFICIENT AS A LECTURE?

A discussion, like a lecture, has different levels of consideration. The most elemental one is informative, where the participants are mainly contributing facts about the topic. Integrative discussion is a step up in that it seeks to relate information in a specific area to information already gained (or assumed to be had) in other related areas of concern. The inductive reasoning about facts, and their relationship should lead to the formulation of concepts which constitute insight and understanding. This ability to make inferences about information, to gain insight and to make predictions, represents the "discipline of the mind" that some feel is the foundation of a liberal arts education. It is another way of saying that some education has occurred, for it calls upon the higher functions of the intellect. Reaching this point is the prime value of the discussion, for each student has an opportunity, or potentially has the opportunity to ask about those points which keep him from getting at understanding.

Once the ability to make inferences is achieved, the student is in a much better position to be analytical about other similar information. An evaluative discussion will then involve analytical thinking, critical assessment of what is a fact (from the reasoning process inherent in the scientific method), and forming judgements about an author's point of view.

The last and highest level sought in these discussions is the ability to use the information discussed, and the insights arrived at to raise new questions for investigation (continuation hypotheses) and to create new ideas.

A lecturer may go through these levels of consideration but most frequently the student must follow passively, or if he is lost, he must not interrupt. If he does interrupt the lecturer, the question is often parried or delayed if it is not on the topic that the lecturer was presenting.

In following such a sequence for discussion not every step needs to be used but the most complete consideration will be made when all of them are used. Discussions may be of three types -- sequential, integrative or open-ended. Sequential discussions lead students from one fact to another until, by inductive reasoning, students are brought to generalizations about biological phenomena. This type of discussion may also lead up to an activity to be done in class, as a home assignment, or in the laboratory. Integrative discussions require that the students use biological and other knowledge in an effort to understand particular aspects of inquiries into biological phenomena. Open-ended discussions usually begin with the consideration of possible solutions to a problem. It may become sequential or integrative, depending upon the direction in which the class takes it.

TYPES OF LEARNING

Intellectual learning, just described, can be described as an increase in the amount of information about something that the learner has acquired. This "discipline of the mind" involves to a very great extent, an increase in vocabulary, since it is largely a verbal process. New concepts and ideas seem to be more easily assimilated if they have names. Exposure to new words (terms) and their associated ideas are characteristic of this kind of learning.

Skills learning has to do with an increase in the learner's skills in the performance of some act. Learning in this sense has to do with the development of manipulative ability with tools, equipment, words, even people. This is often called "training" instead of education. This is largely because behavioral skills can be affected without much involvement of one's own conscious thought. Not all training is devoid of conscious thought and intellectual learning. The ability to write clearly, teaching, the performance of delicate surgery, all require training and skill linked with intellectual activity. At these latter extremes, the learner has acquired some of the "whys and wherefores" that are the reasons for performing the skills certain ways. He has much more flexibility than the person simply trained so that he is not restricted to a certain stereotyped behavior which cannot be adapted to a variety of unique situations that must be met and solved in real-life situations.

Emotional learning involves a change in the learner's attitudes, values, or feeling about a topic. Some like to refer to this as "gut learning." However, it is doubtful whether one can engage in mental activity without emotional activity, and also the reverse. As with training, it is possible for emotional learning to take place without much intellectual involvement or awareness of what is happening on the part of the learner. In this type of learning the change taking place is by direct experience, and to the extent that the learning has not been verbalized (or intellectualized) it cannot be communicated.

There are some who feel that at the college level it is not the function of the school to change people's values, only to expose them to information. On the other hand, many teachers feel that there is little point to a course that doesn't change student's attitudes--whether it's philosophy, science, or sociology. The best teachers probably seek a balance between these two points of view.

HOW SHOULD ONE LEARN TO DISCUSS?

Which of these methods is best for learning to lead and participate in discussions? Is any one or two of them best? Experience has shown that for the most effective development of a discussant, all three methods--intellectual, skills, and emotional training--should be used. Each type has something to offer, but is deficient in the contributions of the others. The intellectual approach can develop the vocabulary without any increased emotional sensitivity to people, or new behavior patterns to go along with greater understanding. Skills training alone in discussion techniques can also neglect intellectual development and sensitivity to others. Emotional change alone, too, can leave one unable to talk perceptively about the information to be transferred. Working on hunches, the emotionally-trained person is less able to use self-analysis or to arrive at self-correction. It can then be concluded that the most successful program for learning to discuss will involve all of these levels of learning or behavior change.

How then can this be accomplished? Teacher and students working together can create opportunities for the practice of discussion skills and join together in directing the learning process.

METHODS OF LEARNING TO DISCUSS

1. Discussion of a Reading Assignment

Make a reading assignment to the class on a topic selected by the teacher (the usual situation) or by the class. Topics selected should make some intellectual demand upon the student in the way of preparatory research--that is, give more than one reference to be read, or assign a topic upon which information will be sought from a number of literature resources. Ideally the topic should be one with which the student can get emotionally involved, like:

Is there an extra-material universe?

Did man evolve from the apes?

Are we what we eat?

Does the father or mother determine the sex of a baby? Why?

Etc.

Note that these topics are stated as general questions in contrast with the case method approach to be introduced below.

2. Role-playing

Let some members of the class assume the roles of personages involved in pertinent questions under discussion and have them express (a) what they think the personages that they represent would say in the given situation, or (b) what they would say if they were in the same position. The situation and dialogue may be written out, as for example in "Robert Brown Discovers the Nucleus" (in Goolsby, 1970). More usually it will be announced verbally. For example:

1) A conversation between the President of the United States and a returned war veteran on the ecological and population control aspects of war.

2) A conversation between a physician and a close relative of a patient who is gravely ill. Should he, or should he not try a new drug, tested in animals, but not given to a person before?

3) A conversation between the manager of a large industrial plant accused of polluting a town's only river and a man who finds that there are no longer any fish in the river to be caught for either sport or food.

Role playing may be used to demonstrate some procedural or interpersonal problem. The discussion that follows is more important than the demonstration.

Example:

Teacher: John Jones will give us a demonstration.

(John Jones goes to the cabinet, removes a microscope, carries it (with one hand on the arm and one on the base) to the demonstration table and sits it down). The discussion of the proper handling of the microscope is the reason for the demonstration (but the demonstration must also be performed correctly).

A second use of role-playing is to provide the actor-student an opportunity to practice certain discussion techniques and skills. Again, the dramatization is for the purpose of stimulating discussion. The emphasis should be on arriving at a generalization instead of giving specific patterns of behavior to be imitated. If students are made aware of this, more learning is likely to occur.

3. Case Method

The case method is used in conjunction with the reading assignment discussion approach, adding a new element. Instead of dealing with a generally-phrased question, the discussion centers around a concrete case, such as a scientific report, or "What should be done about the pollution in the lower Potomac River?" The advantage of the method over the general question is that there seems to be less difficulty in developing involvement in the subject among the participants--a desirable, and hoped-for objective in many education endeavors.

4. Small Groups

This technique is useful where the teacher is interested in researching the interactions of members of a small group (group dynamics). The idea here is to present a provocative question to the group and the teacher then studies the interaction that ensues.

CLASSROOM ARRANGEMENT

It is unfortunate that for ease of janitorial care, most classroom seats are secured to the floor. There are possibly other advantages, too, for having this condition. The disadvantage for discussions is that the arrangement centers on someone at the front of the room and on the chalkboard. That is because, in the lecture system, all attention is on the teacher. If there is a question, it cannot be heard by all and the teacher is expected to repeat it before answering.

In a discussion group where the participants are expected to interact with each other, the usual classroom arrangement is very unsatisfactory. Seats should be arranged in a semicircle so that any student can see and speak directly to a majority (if not all) of those present. This is part of interpersonal sensitivity, since one's facial expression, gestures, as well as his words and tone of voice are part of the language used. Also, it is easier to "hear" when you can see the speaker.

TEACHER DISPOSITION

The presentation of a pleasant disposition is helpful in allaying anxiety on the part of students that they may be punished--verbally and emotionally--for not knowing something. An atmosphere of low to medium anxiety is conducive to learning. High anxiety decreases learning. The high-anxiety, highly compulsive (HAHC) student generally does not like discussion because it may cause him to reveal that he is not as informed as his examination scores would indicate. Also, the information may not occur in a very organized form. Teachers should write salient points on the chalkboard and probably classify points as they are raised or made. Generally, discussion is preferred by the student who is generally also not of the HAHC type, and is willing to think through solutions rather than memorize the pronouncements of others.

THE DISCUSSION SESSION

The ultimate aim of the ISE approach to teaching is to produce classrooms where the methods of teaching are in accord with those which meet the demand by increasing numbers of students for course contents which are more relevant to the present generation of students and which reflects teaching methods which place more responsibility upon the student for the direction which his education will take.

PHASES OF THE COURSE

The biology course consists of discussions and laboratory experiences. The discussion is intended to be the place where the teacher assures himself that the student has arrived at as good an understanding of biological concepts as the present state of knowledge permits. The laboratory has been a part of biological teaching ever since it emerged from medical education as a separate study in the 1850's. Sometimes laboratory teaching methods are didactic and at other times they are inductive. In general, didactic methods are used to teach skills early in the course and then these skills are used to perform experiments which give the student first-hand involvement with the objects of biological science, and their behavior.

There should be an atmosphere of free inquiry about biological objects and phenomena throughout the course, and especially about those topics of most interest to students.

The ideal discussion session occurs in a physical environment which is free from psychological distractions and physical discomforts. It, therefore, must be neat, cheerful, have furnishings which are comfortable but not sleep-producing, it must be properly heated or cooled, have good shadowless lighting, and be well-ventilated.

There should also be an equal individual seat for each individual student, that is, they should not have to sit on steps or on tops of tables, etc.

The teacher may use a few minutes at the start of the session for administrative activity, such as taking attendance and making announcements. (The class may be too involved in discussion at the end of the period for good perception of such items).

The teacher then presents an object, perhaps one of several he will use during the discussion period. The object may be a biological specimen, model, movie, picture, diagram, etc. This is done with a minimum of preliminary comment. Students may begin several ways. One way is by asking questions which the teacher or a student secretary will write down until all initial questions are asked. The teacher will then establish a preliminary order for considering the questions. Students will be asked to answer questions in the light of their assignments and of past discussions by the class. The teacher, or perhaps other students must ask that opinions be supported by reasoning. Conclusions are evaluated for their scientific worth, the implications of the conclusions are considered and possible experiments, resources, etcetera, are talked about. The teacher should now have at hand a second object which forms the basis for the next sequence of considerations.

A second response to the initial object can be contributions by students from their own experiences with the presented object, followed by critical evaluations of statements which either students or the teacher may feel are open to questioning. When "fact" has been separated from fiction and opinion, one or more generalizations are sought. After the implications of the generalizations have been explored and possible next steps have been discussed, such as experiments, the consulting of the resource literature, etcetera, assignments are made and the students sent to the library or to the laboratory to find some possible answers to the questions posed by the class. Some individuals may wish to find answers to their own questions arising from the discussion. The students should report to the class on their findings in the library or laboratory on the same or another day.

The teacher can vary the sequential arrangement of the discussion session by presenting more than one related object for consideration and following through on the one generating the most interest in students. Eventually all of the objects are brought into the discussion. Finally, one (or more) students may investigate questions generated by one or more of the objects presented.

All of these types of discussion sessions have some requirements for maximal educational value.

Students must have some background for discussing the questions aroused by considering the object. This usually means personal experience, or reading with understanding and memory, some written material dealing with the object or the questions it raises.

The teacher must have in mind at the beginning the possible valid generalizations toward which discussions can be oriented by either the teacher or the students.

The most distinctive difference between the TCCP discussion session and a regular college lecture period is the fact that it is a discussion session. Emphasis continues to be placed on the conduct of the discussion session and the nature and quality of the discussion because it is vital that it be a stimulating education experience. The tendency to consider the ability of students to answer a constant stream of factual questions from the teacher makes such a session traditional in that the student is presented with some reading material and then required to memorize it as completely as possible for the oral examination that will follow in class. This is not a discussion, nor does it fulfill the function of the discussion as advocated above.

This questioning technique satisfies the teacher that the student read and memorized the material, but has he learned it? It assures the teacher that the student has covered all of the material in the reading assignment. It assures the teacher that the students know as much as the students in the traditional freshman courses. But, does it assure the teacher that his or her students understand any better what they have read? It is the level of understanding, not memory alone, that concerns us most.

Getting the discussion going and maintaining it requires that questions posed by the teacher not be answerable as so much information, or at least not beyond the first few minutes on the topic. The teacher should be satisfied that the student has read the assignment and is indeed ready to discuss it. Then this information needs to be integrated into what the student knows.

In the inductive teaching style it is important to relate new information to what the student already knows. As William James put it, facts are facts, we have to make them "true." They are true only if they harmonize with what we already know to be demonstrated as true. If not, they lead to an uncomfortable feeling which is interpreted as indicating the information is untrue and therefore unacceptable.

Through integrative and sequential discussions the class can be led through inductive reasoning (not the same as inductive teaching) to generalizations. It is another cardinal objective to have students arrive at these insights or generalizations through inductive reasoning (often referred to as "discovery"). This is important if we are to overcome the student's fear of science and the idea that it is something done only by incredibly smart people like the teacher. Their background, for the most part, has been one of accepting edicts, proclamations, and apparently divinely-revealed statements about nature, made by their teachers. They ought to be led to think through the problems, not to accept solutions from the teacher or authors without having to think (even if they question the validity of the teacher's conclusions or object without thinking through the problem). When the teacher has brought the class along to where they can reach a generalization, they have arrived.

Remember that all the facts are tied together in your (the teacher's) mind but not in the minds of students. Incomplete reasoning, failure to include the details of a reaction sequence or process, and the like, can leave the student thoroughly confused and bewildered while trying to understand a topic that is new to him and that he knows that he doesn't understand. This is one more reason for not rushing through the discussion. Discussions take much more time than do lectures, so not as much information (facts) can be covered per hour as in a lecture. However, in a lecture, practically no understanding can be ascertained and the student's only recourse is to memorize what he was able to copy as notes, or read in the text.

There is need to follow out student interest on a topic or section. It is part of being "relevant" as long as the discussion is kept relevant to biology. If the discussion was not finished when the class ended last time, it is important to review the last few points and see to it that an inductively arrived at generalization has been reached before going on to a new topic for the day. If that takes all of the time, so that the class doesn't get to the new topic for the day, that's all right. If they have read and retained the information assigned for reading on such a day, they are ready to discuss it next time.

It is not necessary to cover everything in the unit but it is necessary to be sure that the generalizations are clearly reached before a new topic is taken up.

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CHAPTER 4--TOWARD A BETTER SYSTEM OF TESTING AND GRADING

TEACHERS MUST EVALUATE STUDENTS

Perhaps the least recreational part of teaching is grading papers. When Northeastern University instituted computer-grading several years ago, it was a great boon, but it could not be used for most kinds of student evaluation--only the scoring and analysis of examination cards. However, since it did analyse answers, the computer output became a tool for the improvement of instruction.

Institutions of higher learning almost always insist upon examinations, although for many college courses nowadays, the professor may decide whether or not he wishes to give an examination. Where classes are small and advanced, he may feel that he can evaluate the students well enough without a formal written examination. Where classes are large, examinations are relied upon. Whether or not examinations are given, school administrations require a grade for each student. This is a code for the teacher's evaluation of the student's proficiency--in practice, his proficiency at taking examinations. Since it is the aim of most schools to either teach or offer opportunities to learn, the grade is considered to be a measure of how much was taught or learned or could be recalled from memory.

WHO BENEFITS FROM EXAMINATIONS?

Who benefits from examinations? The administration gets a grade to show that the learning opportunity they marketed was indeed delivered to the customer (the student), failure usually being the sole responsibility of the student, at least as interpreted by administrations. The adminstration provides buildings, materials and students, but these things do not produce "taught" students. Strangely enough, college administrations do not supervise the teaching that they sell. In the ISE courses the ISE staffs are charged with the responsibility for helping develop the courses and how they are taught. ISE, therefore, evaluates the programs in its own way and has a vested interest in seeing to it that students are graded fairly and in the light of the kinds of activities pursued in the courses.

Teachers benefit from the examination when they can look at the results and take pride in the fact that they did a good job of transmitting knowledge and thinking patterns. Students will look on the examination results mostly in terms of a grade which either rewards or punishes them for their performances.

However, exminations can be an educational tool which requires the student to integrate his information in ways that he may not have done before. It seems in some colleges, perhaps it is more true in larger universities, that the freshman year is one in which as many students as possible are flunked out by means of bad teaching, especially tough (even unreasonable) examinations, and large, depersonalized classes with little help or counseling. The ISE recommended format, followed by its consorting colleges, tries to do the reverse of that by providing interesting curricula, interested and capable teachers, small classes, and frequent opportunities for conferences with the teacher. Actually, if the criteria of admissions officers are valid, then all freshmen should have the mental ability to complete the freshmen year. (It is not believed that colleges would take tuition money from potential students who could not possibly succeed in college. The fact that some colleges register fewer than their anticipated number of freshmen demonstrates the point.) Admissions officers do not appear to try to change the teachers in order to make their forecasts of students' success come true. Rather, they try to determine the type of student which survives in the teaching system their college uses. However, there is a bug. The professors keep outsmarting admissions officers by examining students on that which they did not teach.

School provides a special environment for having real and contrived experiences which can be models for forecasting outcomes to real and possible situations, or for predicting the probable behavior of a great many other possible objects of study not as yet experienced. The proficiency of a student in mastering these goals is included in the evaluation system--usually of limited components at the college level--that we call the grade. The grade is the reward the apprenticed youth in school gets for his work and study. It is reasonably predictive of future school success but does not necessarily predict non-school success because non-school situations are not contrived, as are school experiences.

Recently, there has been little direct emphasis upon how a teacher should go about evaluating student performance in the ISE biology course. The topic has not been discussed in any detail with teachers recently. This does not mean that there has been a lack of interest, for teachers have included in the course units many objective questions for self-tests and regular tests, and also many questions for oral or written discussion. It seems that written examinations are the most-used instrument for evaluating students in the course. Although the term "laboratory-centered" is sometimes used to describe our course, we have little information on how the laboratory performances of students are evaluated and incorporated into the final course grade.

WHAT ARE COMMON TYPES OF EXAMINATIONS?

It is always easy to start a discussion with teachers about which is better--objective, short answer questions, or more subjective, discussion or essay-type questions. Double-choice (true-false) and multiple choice questions (whether 4 right-1 wrong or 4 wrong-1 right) provide the student with the answer if he can recognize it. Cues to answers may or may not be provided in essay questions, but in the final analysis, essay or discussion questions get graded objectively. That is, the teacher will ask himself what proportion of the expected number of points did the student include in his discussion?

Practical examinations, dealing with objects with which students have had direct experience, are frequently used in biological laboratories where morphology is stressed. Generally, they are designed to test the memory of students about what they have seen, rather than apply what they have learned of the solution to a problem, either theoretical or practical, or to the performance of a task as in doing an experiment. The question to ask here is which one, if any of these kinds of examinations, is better than the others? Perhaps none--anymore than a grade of A is better than 90%, or a grade of B is better than 80%.

Some variations on these types of examinations (objective, essay, and practical) are little used. Unassembled examinations, (the "examination" is written outside of class) are good for helping the student look up and pull together information or ideas, but, of course, does not indicate what he has learned. Open book tests seem to abolish student confidence in what they have learned, probably because of the intense anxiety resulting when they realize that they don't know exactly where to find information, or that there is a mass of information that they don't really know.

A good library is one of the most important tools of the scientist and scholar. The scientist needs to know what others have found and he also needs to let others know what he has found. Therefore, the writing of a laboratory research paper, or even a literary research paper (in this case on a biological topic), constitutes a test of inductive reasoning as well as a practical examination in the use of the literature.

All examinations need not be long. The quiz is very useful, too. An announced policy of unscheduled quizzes (about 10 minutes long) has a good effect on distributed study--*i.e.*, doing assignments when they are given compared with cramming before longer examinations. In a course, such as the ISE courses, where discussion is emphasized over lecturing, it is essential that the class read the background material for the discussion before class meets. This is in contrast with a course of lectures where it is unnecessary to read the assignment until examination time comes around. The lecturer consistently seeks to give clear expositions which lucidly and logically explain a point of view (to the exclusion of other points of view), so that reading background material is used to help explain unclear points for the student. But the fact is that the student frequently does not find clarification and may not get it even in a conference with the teacher if he has not done additional reading.

MEMORY AND RECALL

In the discussion-type courses, the teacher seeks to help the student arrive at greater understanding (*i.e.*, wisdom) of the subject by helping him to explore that which he does not understand or understands poorly. However, this is difficult, if not impossible, if the student does not know what he does not understand. The task is greatly facilitated if the student has some previous knowledge, either directly-experienced, as in the laboratory, in society, and in the field, or through reading the ideas and experiences of others.

It ought to be clear that both of these approaches to teaching have the objective of giving input to the memory banks of the brain via pathways permitting a low threshold of stimulation for easy recall. Of the two, the discussion method certainly provides the in-out kind of thinking that reinforces the specific nerve circuits in the memory areas of the brain, requires integration of various related idea-circuits, and better encodes the recall signals.

the recall signals.

Memory deals largely with informational bits we call facts. Facts must be filtered through a "false-maybe-true" switch for evaluation, very much like an IF statement in Fortran computer language. That is, IF (proposition)-, 0, + GO TO n. In such a shorthand statement -, 0, + represent the sign of a number being evaluated. It is then switched to specific addresses (GO TO) in the program, e.g.,: IF (x) is negative, GO TO 29; IF (x) is zero, GO TO 5; or IF (x) is positive GO TO 101, where additional operations are performed or output (behavior) is directed. The whole computation is aborted and an error code is reported by the computer if there is no such address to GO TO. In the brain one gets a DON'T KNOW or confusion signal. The chances of finding appropriate "handles" or addresses for information are greatly enhanced by discussion.

THE PROGRESS INVENTORY

The Progress Inventory is a pre- and post-test given to measure the increase in a student's knowledge or change in his attitudes toward a unit topic. This has shown itself a useful tool for measuring the effectiveness of teaching and learning. Examinations and quizzes are given following instruction to measure what the final state of learning and recall is. These tests do not tell the teacher where the student started. It is useful to know if students generally know a lot or a little about a subject to be taught. A student may make a score of 70 on a quiz. That is usually equated to a low C in the grade book. But where did he start. If he could have scored 50 before instruction, he learned a little. If his starting score would have been 10, a teacher could be justly proud of such progress. The pre-test establishes this level of starting competence.

We have not found a suitable way of working a large increase in knowledge into a final grade in the course. This is partly because of the fact that if students know a large increase between their pre-test and post-test scores will benefit their final standing in some way, they will purposely make low or zero scores on the pre-test.

We have found that the cooperation of students can be gained by a simple explanation at the beginning of the term that there will be some pre-tests to determine the level of knowledge as a guide to teaching. (This is, after all, the main value of the pre-test.)

To reduce the amount of separate periods we have taken a segment of the next hour exam (post-test) as the pre-test. Pre-test scores are not given to students until after post-test scoring has been done and the gain (or loss) calculated. This group of about 20 objective questions form the first segment of the next hour examination.

There were reasons why students liked this arrangement:

It gave them some examples of the kinds of questions which would be asked.

It tended to indicate to them some of the important concepts and information to be encountered in the upcoming instruction.

It must have indicated to many of them something of their level of information and therefore an index of the amount of learning and study they might achieve. That is, they knew about how much, after that, they did not know.

Our experience with the progress inventory was that

(1) It helped define the starting knowledge of the class.

(2) It motivated the students because they gained some insight about their need to learn and some of the topics about which they discerned their need to know more.

(3) It brought a sense of accomplishment when a student scored low on the pre-test and passed the post test. By traditional standards it is disappointing to the teacher to find a lot of D's on the hour examination. When such students showed 300 to 400 per cent increase between pre- and post-test scores, real progress was indicated.

SOME SAMPLE TEST QUESTIONS

Essays (Written Discussions)

Example 1.

Discuss William Harvey's contribution to the development of the scientific method in biology.

Ans. Because Harvey had been a medical student in Padua, he learned the kind of careful observation restored to biological and medical study by Vesalius. When he returned to England he became interested in embryology and the movement of the blood. He performed experiments to gain new knowledge, he measured his results, and he was able to generalize from the new facts, a principle, the circulation of the blood in higher animals.

(Comment: The question asks for a limited amount of information and is easily evaluated.)

Example 2.

Discuss the cell.

(Comment: This request is too broad for even good organization in an hour. Anything the student remembers would probably be the basis for evaluation. In this case (a poor one) one then weighs right points against wrong ones, but in general it may be difficult to assess whether the student actually understands even the main aspects of the cell, its function and its significance.)

Example 3. What basic function is performed by the Krebs cycle?

Ans. The extraction of carbon dioxide for discard, and the collection of energized hydrogen for use in ATP production.

(Comment: The answer required only calls for memory of a couple of facts, so that the integration of information is limited. Since integration of information is a major reason for the written discussion this information would be handled better in objective questions.)

Objective Questions

Example 4. Starfish are good examples of mollusks.

(a) true (b) false (c) maybe

(Comment: The statement is unequivocally false. The choice of "(c) maybe" is counted as wrong. It is used as an attractive alternative for guessers.)

Example 5. Which of these men did not participate in the formulation and acceptance of the cell theory?

(a) Robert Hooke
(b) Jean Lamarck
(c) Mathias Schleiden
(d) Theodore Schwann
(e) Rudolf Virchow

(Comment: The correct response is (a) Robert Hooke. Hooke first named the cell but did not theorize about all living things being made of cells. Note that all choices are:

.logical.
.about the same length.
.not hinted at in the question.

An advantage of this form of choices (4 right, 1 wrong) is that:

.it emphasizes right information
.there are more right facts taught.
.wrong statements are harder to come by.

Example 6. Which of the following metal atoms are part of the chlorophyll molecule?

(a) iron
(b) copper
(c) magnesium
(d) manganese
(e) vanadium

(Comment: This is the most common form of multiple choice question. The right answer is in sight, if it can be recognized. The right answer is arrived at mentally and then matched to the list. From the standpoint of writing it is more difficult to get 4 wrong, plausible choices than 4 right, plausible choices.)

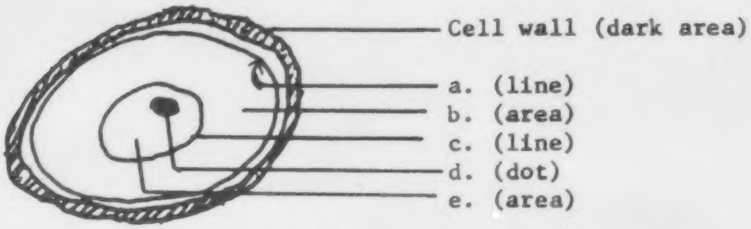
Matching questions are the same as condensed multiple choice in which all of the choices apply to each question in the list.

Example 7. The sequence of phases in mitosis, beginning after interphase is:

21. First
22. Second
23. Third
24. Fourth

. Interphase
a. Metaphase
b. Telophase
c. Prophase
d. Anaphase
e. Prometaphase

Example 8. Match the structure to the name.



Cross section through a cell

31. cell membrane
32. nucleolus
33. cytoplasm
34. nuclear sap

(Comment: Where machine scoring is used the list of choices is limited to five. Sometimes one sees long lists of choices. These require more time to read and thus absorb (waste) time. Note that there is one more choice than there are questions. This is so that there will still be a choice of two items for the last question answered. Note that guide lines must go exactly to the structure indicated. The part of the diagram can also be indicated as space, dark area, line, dot, etc.)

Completion Questions

Example 9

41. The group that shows what is normal, in an experiment is called the ____________________.

(a) control group.
(b) dependent variable.
(c) the experimental group.
(d) independent variable.
(e) none of the above.

(Comment: The structure is basically 4 wrong and 1 right multiple choice. Where the choices are not supplied (hand-graded) the answer must be called up from memory. Where choices are given, the correct answer from memory is matched to the list. The "None of the above" choice is a wrong choice since "(a) control group" is the correct answer.)

LABORATORY EXAMINATIONS

The foregoing almost always applies to the discussion session (which replaces lecturing). What about the laboratory? Laboratory work in the sciences grows out of the tradition in medical education that the physician needed some direct experiences with anatomy, pharmacology, physiology and the like, before he began to deal with sicknesses and disorders in human patients. When Biology began to emerge, about 1850, as a study separate from medicine, the method and its validity were already well-established. In those days the laboratory was a place to demonstrate that the incredible assertions of the professor could be shown to be indeed true. It was a big visual aid, but also a center for the didactic instruction in method and technique. These are still valid uses of class laboratory, but we seek to get somewhat away from that kind of usage--to make the laboratory a place to find out things, to find answers to questions raised, not so much by the teacher as by the student, at least sometimes.

Laboratory work is a cooperative effort between a student, his partner(s), the laboratory teacher, literary resources, and other students. Ideally the student should be inquiring and acquiring information about the objects or phenomena at the center of the laboratory activities. Under these circumstances it hardly seems consistent to make the laboratory report a completely competitive instrument for evaluation. It should be a report of what the student found and a more-or-less detailed explanation of his understanding of what he saw or did. If there is competition, it should be the student competing with himself, with encouragements from his teacher at all times to do better and better. This would indicate in a rather general way a method of evaluating laboratory reports. If they are routine reports of the data and answers to previously-posed questions, they should be read and corrected by the teacher so that erroneous ideas do not persist. An essentially "pass-fail" type of grading should be used. Three marks could be given:

A -- for a superior job and a well-above-average understanding of the laboratory work (100% to 90% perfection).

S -- for "passing" work. The lower limits of "passing" should not be "too low" (90% to 70% perfection).

I -- should be given for incomplete work or for work that has not been performed or work that has been performed at less than the "passing" level, (less than 70% perfection).

These marks--A, S, and I--are not computable. Therefore, the laboratory work and the completion of routine reports should be considered a requirement of the course and no final course grade would be issued without the satisfactory completion of all assigned laboratory work. This would beg the question as to how the reward of a recordable laboratory grade could be worked into a system of student evaluation. Two suggestions can be made. First, about 25% of the questions on written hour and final examinations could deal with aspects of the laboratory work as such--with the experiences in the laboratory, experimental findings, the operation of the instrumentation, the principles exemplified, or the working of the scientific method in the solution of a problem. The second way is through the practical laboratory examination. Such examination should stress the use of the techniques learned for the solution of a question or problem, rather than to remember, for example, the ways which a liver cell differs from a kidney tubule cell. Such minutia should be left to more advanced courses. Some examples of items in such a practical examination as described would include items like these:

1. Make a temporary wet mount of a protozoan or algal culture and find (but not necessarily identify) the cell under the microscope.

2. Make a temporary mount of some cell and estimate the internal pH. (The method and the choice of indicator from among several to choose from should be correct).

3. Determine the pH of a biological fluid (fruit juice, plasma, or urine).

4. Correctly perform the asceptic transfer of a pure culture from one tube to another.

5. Correctly remove asceptically a pipet from a can or from its sterile wrapping, making a pipet transfer to a water blank, properly mixing it and spreading a petri dish correctly with the diluted material.

6. Make a chromosome squash preparation.

7. Identify the parts of a flower not studied in class (where a flower has been studied).

8. Demonstrate the method of injecting fluid into the dorsal lymph sac of a frog.

9. Selection of the proper reagents for a test to determine the presence of glucose, amino acids or proteins.

When can such practical examinations be conveniently given? It depends upon the amount of assistance available to the teacher. If one allows 30 minutes per student, and there are 25 students in the class, then 12 and 1/2 hours are needed for individual testing, probably carried on during laboratory time with someone taking the responsibility for class supervision. A second method is to place the materials and the task question at each work space. Have the student leave his notes at the side of the room, then give him about 30 minutes to complete the task, after which time the teacher and the assistant will spend another half-hour evaluating what was done.

Many exercises in the course may be used as the basis for a scientific report. These take some time, and familiarity with the use of the library to complete satisfactorily, and may be graded using more conventional values (percent) than the A, S, I system suggested for routine reports. There should probably not be more than four or five such reports during a semester.

COMPONENTS THAT SHOULD BE CONSIDERED

Since discussion is an important part of the course, some evaluation should be given to the amount of participation a student does in it. This would include not only recitation about reading assignments, but his creativity and inquiring spirit, whether or not his interest extends beyond the class time so that he brings in news clippings of interest, specimens that are unusual or interesting for the observation of the class, and so on.

The foregoing discussion, then, suggests, in fact, points out the incompleteness of not including some other components other than the written examination in evaluating student performance. Instead there is a list:

Discussion participation, creativity, etc.

Quizzes on discussion and laboratory work

Written examinations
(Perhaps 75% on discussion, 25% on laboratory)

Laboratory practical examination

Written scientific reports

Completion of all laboratory assignments with a grade of A or S.

Questions which remain include, how much weight should each of these components get? and how can time be budgeted to accomplish it?

The above scheme tries to overcome the separation so often felt between the discussion and the laboratory work into separate courses in the minds of many students, with separate content, separate teachers and separate purposes.

Student-nature being what it is, knowing that all aspects of the course, not just the written examinations, go into his evaluation, should be a strong stimulus for the student to perform at his best in all of these activities.

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APPENDIX A -- GENERAL AIMS AND GOALS FOR THE COURSE

The curriculum materials in biology may be divided into three categories.

Firstly, there are reading materials. These serve the purposes of introducing the student to a new body of information, to summarize or review information, and to correlate ideas needed for intellectual discussions in class and leading to generalizations which are integral to the study of biology. They also serve to improve comprehension or scientific terminology and language and increase comprehension by identifying and associating scientific terms with the course experiences, with the discussion content, and with laboratory skills and experiments. In the laboratory they may be used to give directions for the various activities. They are also used in various ways as resources which students may use to strengthen the viewpoints they take in the interpretation of their experimental data. Thus, in these and other ways, the reading materials function to inform, review, and arouse curiosity and more interest in the various topics by providing information for the discussion of the ideas involved.

Secondly, there is equipment. The equipment is comprised of tools which basically aid the hand, the eyes or the ears (or other sensory receptors) in the production of sensory input to the brain. There, mind can perform the intellectual integrations which constitute one's perception of natural phenomena.

Thirdly, there are laboratory materials. These are the "objects" for study as examples of a class of objects which are similar or related. It also includes ancillary materials such as chemicals which are used with the equipment in the performance of exercises (for developing skills) and experiments (for developing understanding of the ways in which a scientist gathers information and arrives at conclusions).

Material Goals

The general aims and goals which these groups of curriculum materials seek to accomplish include these:

(a) Embodying the topics of interest to students, as teachers have perceived this interest from 1967 to date. In addition, to embody enough other information to make the topic "rationally complete" in the light of general usage in biology. However, not everything many consider "important" or "useful" is covered, but enough is covered, and in sufficient depth, to give the student an understanding of the contributions of the various areas of biology to human welfare, and to introduce the student to the ways in which information is gathered and interpreted in each area.

(b) Providing a guide to the use of curriculum materials so that teaching may be done in the inductive manner. Teaching materials make possible particular styles of presentation. Our guide encourages inductive teaching and seeks to prevent a teacher from using any other style of presentation. Only a few materials really permit inductive teaching. These materials, therefore, meet our specific needs since materials useful for teaching an introductory course in biology by inductive methods are relatively rare.

(c) Providing the teacher with as many references, questions, lists of visual and teaching aids, laboratory experiments and lists of materials needed, as would normally be usable within the three-week (more or less) period of teaching as covered by the unit. This is done through the Teacher's Guide to Laboratory Activities and the Teacher's Guide to Classroom Discussions.

Student Goals

The general behavioral objectives sought for students taking or completing the course would include:

(a) Seeing biology, and science in general, as a process which not only solves problems but which also creates new things.

(b) Arriving at an attitude of objectivity through critical thinking and inductive reasoning about that which would be a scientific fact.

(c) To have an appreciation of the laws of random events and how, through the proper philosophical readiness, scientists make their discoveries.

(d) To have a general knowledge of the world of living things and man's relationship to its various levels.

(e) To better understand natural occurrences by the application of biological principles.

(f) To develop observational skills through active participation in scientific experiments and exercises, and to arrive at generalizations through inductive reasoning.

(g) To be able to read the scientific literature in biology with a reasonable understanding of the basic scientific terminology.

Teacher Goals

Goals orienting toward teacher-student relationships would include:

(a) The use of inductive reasoning for reaching generalizations whenever possible.

(b) Involvement of the student in the learning process as much as possible.

(c) Stimulating students to learn by giving them advice, self-helps, and opportunities to learn about the world of living things through readings, discussions in class and during conferences, and through laboratory and field experiences, allowing the student some choices, yet maintaining some discipline without authoritarianism.

(d) Development of an attitude of quiet confidence in their own preparations so that they do not display behavior which would indicate an anxiety about their information nor embarassment at not knowing every fact.

(e) The encouragement of good study habits, budgeting of time for the course work, and high performance in the course growing out of good preparation on the part of students.

(f) Development of sensitivities to topics in biology of interest to students so that classroom experiences will be made as meaningful in students' lives as possible and relevant to the goal of having some application in modern life situations.

(g) The ability to enter creative states of mind so that current materials may be improved to bring out the most useful experiences to the student for understanding biological concepts.

(h) Reading at least one basic science journal and one science-teaching journal regularly to keep abreast of current publications of interest to them personally and applicable to course content, and that some ideas about current teaching techniques may be appreciated in relation to the teaching program in which they are engaged.

(i) Becoming skilled reporters of student reactions to teaching materials and methods and to subsequently write these reactions in reports and publications.

(j) Learning to make their presentations in such a way as to arouse the curiosity of students and motivate them to further study and work within and outside of the classroom.

(k) To extend the attitude of the scientist, that any good or worthwhile discovery not become the secret property of its discoverer but that it be freely shared with colleagues inside of and outside of the TCCP.

APPENDIX B -- THE STRUCTURE OF THE UNITS

The Units in this book have been revised by the authoring teachers and the ISE staff from the intermediate publication, CRG Biology Teacher's Curriculum Guide, 1969. However, many of the features of that work have been retained, so that the present Teacher's Guide to Classroom Discussions for Biology is still a book of resources for the teacher. The units contain features aimed at providing teachers with literary and audio-visual teaching aids, objectives, discussions, and approaches for the inductive presentation of the concepts to be conveyed in each section. The Units have been organized as follows:

- Foreword
- Introduction
- Progress Inventory
- References
- Topic Outline
- Annotated Outline
    - Specific References
    - Alternate and Supplementary Reading
    - Teachers References
    - Exposition of the Outline
    - Approaches
    - Discussion Questions
    - Objective Questions

Foreword

Each consultant that worked with teachers in developing the Teacher's Curriculum Guide for 1969 wrote a foreword to the unit they helped to design. In 1970 some of the outlines were revised to meet unforeseen needs in the course, but we owe these able scholars and scientists our gratitude and thanks for sharing in the problems of organizing some scattered ideas into a rational series of up-to-date considerations.

Introduction

The main ideas and the objectives sought by the unit are set forth in the introduction.

Progress Inventory

This feature has been described in Chapter 4. These questions are intended for use in a pre- and post-testing procedure to determine the advance in score (as a measure of learning) resulting from the teaching of the unit. The pre-test gives students some idea of the kinds of information covered in the unit and enables the teacher to gauge the areas of strength and weaknesses in the information of the student before instruction begins, thus providing a key to which areas need the more careful attention.

References

The references to books, articles, papers, films, filmstrips, filmloops, and other teaching aids are found in the front part of the unit.

We think that it is important for the reader to look through the reference list before reading the rest of the unit.

Topic Outline

For most courses the textbook outline is the curriculum of the course. In this course the Topic Outline is the basic curriculum around which all of the discussion and activities are generated. The reading material then is selected to support the outline and therefore the reading material takes on a secondary relationship to the outline. This also permits more flexibility in the use of the adopted reading materials by defining what information is desired.

Annotated Outline

At the beginning of each section there is listed:

Specific References for assignment for student reading. These come from different books in different units. A survey of students in 1969 showed that they did not like large (thick) textbooks. Somehow they seem formidable to many students. So most required reading comes from paperbound books that are not very thick and seem less threatening to many students. This does not mean that the reading assignments are correspondingly easy. It only means that the committees of teachers felt that the reading in these references was most appropriate for the part of the outline for which they are assigned.

Alternate References are generally taken from standard textbooks in introductory biology. They are given in case the specific reading is not immediately available to students.

Supplementary Reading is not required, but is good to do. This usually consists of original scientific reports, Scientific American texts, and the like.

Teacher References are useful for teachers but generally are too difficult for beginning students to read and understand easily. Deeper understanding of the topics is a prerequisite to making more simplified but truthful presentations of the more complex topics.

An exposition of the outline seeks to provide a description or an indication of about how detailed the presentation should be and what concepts should be emphasized in each section. The content and concepts in this section merit the careful attention of the teacher. Remember that this course will not attempt to cover all topics and subtopics in biology. It will omit many that a large number of biologists will agree are "important". The aim is to develop understanding of a limited segment of biological information, and with some insights; into how biological scientists proceed to find out information, and something about how they think when they generalize to conclusions about their discovered facts and data. Parallel tests given to program students and regular students in biology departments show that having been given less information, but having understood it better, program students score slightly higher on the tests.

Approaches indicate various ways in which the attention of the student can be attracted toward relevant biological objects for the induction of responses from students, and for motivating them to want to study the principles and other abstractions associated with the various topics. The ability to verbalize about objects involves translating their direct (emotional) experiences into words that can be stored in modes that are easy to recall verbally.

A variety of questions are given, usually at the end of each section, but sometimes at the end of the unit. These are usually designated as Discussion Questions for use in the discussion period, for home assignment or for use on examinations. The same is true of the Objective Questions, although they are not intended for use in discussion sessions. They are useful as self-tests, for home assignment, and for use on quizzes and examinations.

Intended for use with this Teacher's Guide to Classroom Discussions for Biology are the two companion laboratory books, Teacher's Guide to Laboratory Activities for Biology and the student laboratory manual, Laboratory Activities for Biology, both also being publications of the Institute for Services to Education.

In a Statement of Purposes (Preface) to the Teacher's Guide to Laboratory Activities for Biology, the authors point out that:

> "This Guide is prepared for teachers who have students using the manual Laboratory Activities for Biology, prepared and published by the Institute for Services to Education. The Guide contains some introductory remarks for teachers, lists of materials and equipment, methods of making solutions and other preparations, suggestions for introductory discussions with the class, and procedures for doing the various exercises. It also contains answers to discussion questions, but does not give sample data for the experiments. The student manual is not the place for much of this information because the thrust of the teaching in these laboratory classes should be to let the student find out most of this information through his own efforts. We hope that the material has enough flexibility to allow the teacher to express his or her own creativity, yet structured enough to give the student a feeling that he is proceeding properly through the activities.
>
> This Guide is prepared because biology teachers have varied backgrounds and some may have more information in some areas than in others. If this Guide can help reduce the time necessary to prepare for laboratory classes, we hope that the time gained will be devoted to teaching activities as such. The second section of this compilation is devoted to guides for each of the experiments in the student manual, but the actual directions should be consulted when following this teacher's guide for any particular exercise.

The Table of Contents for the Teacher's Guide (less Prefacing pages) is given below. Part II is also the Table of Contents for the student manual Laboratory Activities for Biology.

PART I -- VIEWPOINTS ON TEACHING THE ISE BIOLOGY LABORATORY

SOME WAYS OF USING THE STUDENT MANUAL "LABORATORY ACTIVITIES FOR BIOLOGY" 1

THE LABORATORY AS A PLACE TO "FIND OUT" THINGS 3

BEHAVIORAL OBJECTIVES FOR STUDENTS AND GOALS FOR TEACHERS 4

THE SCIENTIFIC METHOD AND MOTIVATION 5

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3	1,2	DIFFRACTION OF LIGHT INTO ITS SPECTRUM
4	1,2	THE MICROSCOPE AND MICROSCOPY
5	2,3	STERILIZING AND STERILE TECHNIQUE
6	2,5	EFFECT OF ULTRAVIOLET LIGHT RADIATION ON THE COLOR OF *SERRATIA MARCESCENS*
7	2,3	BUFFERS AND INDICATORS
8	2,3	COACERVATES AND EMULSIONS
9	2,3	WATER CONTENT OF VARIOUS TISSUES AND CELLS
10	2,3,7	CELL TYPES
11	3,6	TYPES OF FOODS FOUND IN CELLS AND TISSUES
12	3	DIFFUSION, OSMOSIS AND ACTIVE TRANSPORT
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15	3,5	CHROMOSOME MOVEMENTS DURING CELL DIVISION
16	3,5	CELL DIVISION
17	7	THE PHYLA OF THE ANIMAL AND PLANT KINDGOMS
18	2,6,7	COMPARATIVE ANATOMY OF SOME SKELETAL FEATURES
19	4,6,7	DISSECTION OF THE FETAL PIG
20	4,7	ASEXUAL AND SEXUAL REPRODUCTION
21	4,7	REPRODUCTIVE STRUCTURES IN FLOWERING PLANTS (ANGIOSPERMS)
22	4,7	SEED AND FRUIT PRODUCTION IN FLOWERING PLANTS
23	7	MONOCOT AND DICOT SEEDS, SEEDLINGS AND LEAVES
24	4	HISTOLOGY OF THE FEMALE REPRODUCTIVE TRACT
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29	5	THE INHERITANCE OF GENETIC TRAITS
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37	4,6,7	INFLUENCE OF THYROID HORMONE ON RATE OF DEVELOPMENT
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41	8	TERMITE-FLAGELLATE INTERACTION
42	8	GROWTH OF A POPULATION

INSTITUTE FOR SERVICES TO EDUCATION, INC.

TEACHERS'S GUIDE TO
CLASSROOM DISCUSSIONS FOR
BIOLOGY

PART II

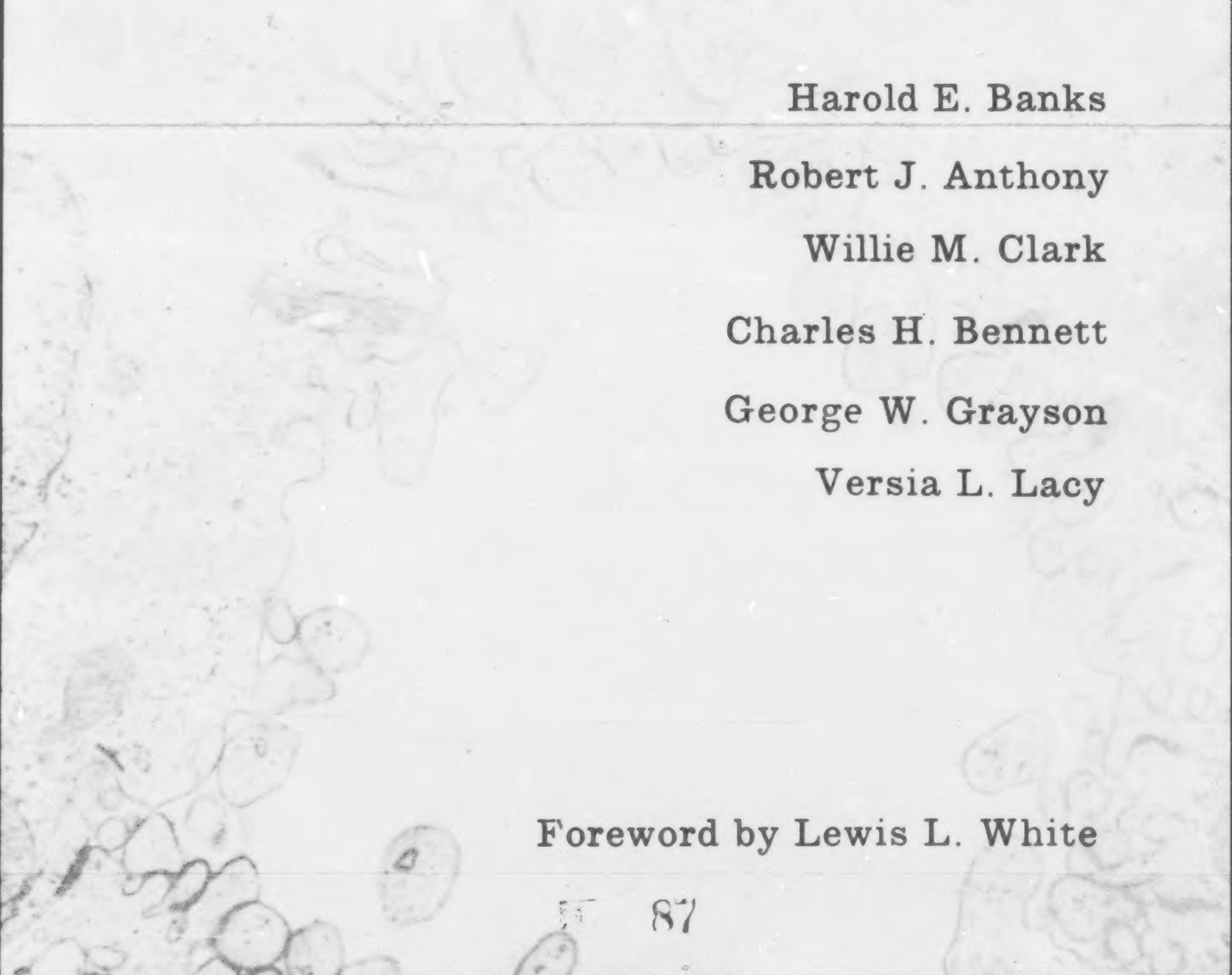
UNITS OF STUDY

UNIT 1

THE NATURE OF SCIENCE

Harold E. Banks
Robert J. Anthony
Willie M. Clark
Charles H. Bennett
George W. Grayson
Versia L. Lacy

Foreword by Lewis L. White



FOREWORD

Modern man, it is alleged, is increasingly looking to science as the best means available to him in his attempt to know his world and solve his day to day problems. He sees how science has changed and continues to change his society. He knows that the products of scientific endeavor have affected his moral outlook and his relationship with other men. Science has improved man's health, increased his longevity and put into his hands weapons with which he can destroy himself. Science has taken the rigor out of work, shortened the work day and provided man with more hours of leisure. The possibility exists, some men believe, that science may ultimately be able to create a kind of ideal world environment in which man can live virtually free from destruction. In a word, science has been glorified.

The glorification of science by modern man makes it imperative that the scientific community add to its lists of responsibilities the job of putting the society in the proper relationship with science. This job is primarily the task of those scientists who work as teachers at all levels of education. It is their job to provide the kinds of experiences for students, particularly, and for the larger community, generally, that will enable them to see science as it really is--as one of the areas of man's knowledge created by man and modified by man.

Although science is very much in the foreground these days, with the newspapers talking about it at great length, and with references to scientific endeavor in other communications media as television and radio, there still seems to be a fairly widespread lack of understanding of just what science is and how it progresses. The public image of the scientist often tends to be that of one invested with peculiar magical powers, occasionally a benevolent being, though more often one giving rise to disastrous inventions. Maybe others see him as a man shutting himself into a laboratory and in his lonely and solitary way playing with test tubes, retorts and a bunsen flame; or still yet, someone leaning back in a comfortable chair in a darkened room and thinking. We might then agree that a gap exists between the scientist and the layman; a gap which must be bridged in order to establish effective communication between the expert and the ordinary man.

A recent show on Broadway has a tune with lyrics which ask:

> "Where am I going? What will I find?
> What's in this grab-bag that I call my mind? . . .
> Looking inside me, what do I see?
> Where am I going? You tell me."

Examining this portion of the lyric and applying it to our present classroom situation provides an excellent opportunity for us each to define our roles with respect to the teaching techniques we would like to use in this course.

Let me cite another example. There was an expression on a college campus a year or so ago that was being used by many students like yours--the expression, "Whatameaname". Taking time to filter this a fraction, we find that the filtrate translates--"What does it mean to me?" Or, to use another way of saying it, "How relevant is it?"

My purpose then as a teacher in this course is simply to assist in helping develop some concept of what science is, and in particular to show how communal an effort it is, and to then go on and assist in the establishment of some meaningful relationships with the sciences given--your own framework of reference.

Let us look at the problem of explaining science to the millions of people who night after night enjoy Westerns, boxing, go-go girls, James Brown, the "It's your thing" tune, etc. One cannot think vividly about millions of people; so, let us narrow it down to your students--first year in college--not necessarily oriented in terms of science as a major field of study--others not committed to any particular discipline. Agreed, they probably have nothing against highbrows and scientists, but among many of you there may be the prevailing philosophy--there's no call to be interested in them any more than they are interested in me. "Live and let live" could be the motto. Again, there is the gap to be bridged which I mentioned earlier.

There are those who say that this gap does not matter very much, that there has always been some failure of complete communication between specialists in different spheres, so why should we worry about this present-day illustration of an age-old difficulty? It is not as easy as that. We are talking about mutual intelligibility between scientists and ordinary people. It is not as if we were concerned with music or painting or literature. There are many people who manage to live happily without understanding what the arts have to say to them. But in these days the impact and meaning of science cannot be treated as if they could be ignored.

As everybody knows, the implications of science for the everyday life of the ordinary man are immensely serious and immediate. Examples are commonplace, from pure water through diptheria innoculation to the world's food supply. These are scientific contributions which are immediately and daily relevant to the normal life of everybody. We do not need to think in terms of H-bombs to realize what is involved. In fact, it is in the ordinary ways we take for granted, rather than in the dramatic threats of cataclysmic events, that the relevance of science to our daily lives is most clearly shown. It is far too much with us to be ignored. If it cannot be ignored, it is just as well that it should be understood, by as many of us as possible, as far as it may be.

Therefore, the unit of study designed herein is an attempt by science educators to provide those relevant experiences. It is an outgrowth of the training and background experiences of educators who work in Black schools in the United States and who interact with one another. Although the designers work in such schools, the experiences provided herein are aimed at any and all students who study science since they are educationally sound and scientifically correct.

It is the hope of the unit designers that teachers will find the unit a model to be used by them in designing experiences for their students at the schools in which they work.

Lewis L. White
Dean, College of Sciences
Southern University

THE NATURE OF SCIENCE

INTRODUCTION

One measure of civilization is man's understanding of the natural world and of his place in nature. In his search for this understanding, man has called upon magic, demons, spirits, gods, and essences to help him explain some of the perplexing and fearful events of nature. To understand the nature of biology it is necessary to understand the meaning of science.

This unit is intended to enable the students to develop scientific attitudes and to acquaint them with scientific devices to solve problems--be they quantitative or qualitative. If we consider general objectives, we might list the following:

> Understanding the nature of science as a vigorous interaction of the facts and ideas.
>
> Acquainting students with the physical and chemical nature of matter in the universe and its varied forms.
>
> Developing skills in the use of the laboratory instruments for observation and measurement.
>
> Developing skills in converting units of measurement into the metric and English systems.
>
> Understanding the scientific efforts in the study of the physical and biological environment.
>
> Helping the student to understand the interrelationships between the physical and biological phenomena that lend themselves to direct or indirect observations or measurement.

Specifically, this unit is designed to point out the characteristic features of that area of man's knowledge called science. A block of experiences are provided which should enable a student to arrive at his own understanding of what scientists seek to do. In addition, this block of experiences will show how the scientific body of knowledge has come to be and why that body of knowledge is forever changing and growing.

The Scientific Method

References: Lachman, (1956); Goolsby (1970) pp. 1-24 to 1-26

General Approach

Fact and fallacy are often so close to each other that sometimes "truth is stranger than fiction". Therefore, the scientists, from ancient times, have faced the prospects of (1) finding a practical procedure for the discovery of new information (facts), and (2) a method for checking to determine if presumed facts are really facts. Both of these prospects have been included in the method of reasoning we call induction.

In the Greek period there was a need to restrain fantasy (magic) by the impact of external reality, by collecting observations, and by building a new basis upon which science could rest. Aristotle and Vesalius both had the *static* view. That is, for them all of the facts were already in "existence" but were hidden. It was the scientist's job to find them. This is the traditional view of induction both as a creed and as a policy--a prescription for acting correctly toward nature's benevolence to scientists. *This view of induction has been superceded* by Einstein's *dynamic* view of science: we help shape the world as it molds us--there is genuine interaction between scientists and nature and between internal and external reality. Once fantasy has been subdued and tamed, it becomes the disciplined imagination of the scientist, and this disciplined imagination gives rise to *creativity* in science.

We gather particular bits of information through our senses and from these we generalize to a theory or law by inductive reasoning. The theories and laws arrived at by this method represent true knowledge. For us, as for Aristotle, the object of science is to find universal truth. Since the natural laws so discovered state unvarying causes for natural phenomena, induction becomes a scheme for discovering these causes or laws and their universal truths.

If we can list all of the possible bits of information about a phenomenon we may make an obvious conclusion by *perfect induction*. This can be tedious. Even Francis Bacon thought that "induction which proceeds by simple enumeration is puerile (juvenile), leads to uncertain conclusions, and is exposed to danger from one contradictory instance." This coincided with his attitude toward nature, for he was active in making experiments, and thus exercising control over limited portions of Nature. However, we find that science has changed since Bacon's time, being more complex than was thought during the Renaissance.

Discovery is not all that science does. If we take the static view of nature and of knowledge, we can never succeed in describing properly what science is, nor what it is that science does. We encounter insoluble dichotmies like deciding which is more important--discovery or invention? We need to acknowledge again that only with a dynamic view--such as seeing nature as process--can one explain science. Also, rather than argue the importance of discovery *vs*. invention, we have to acknowledge that science is a creative activity.

Our imaginations are fired by experiences but the experiences we have are the result of our disciplined imagination. This out and in movement (going outside ourselves, then returning again) is the essence of the dynamic process by which we build up reality. Modern science, which has gone through a series of in and out movements, of abstractions and generalizations, has reached a level of experience very different from that of everyday life. On a simple level we imagine possibilities and formulate hypotheses about such abstractions.

A theory or *hypothesis* is substantiated or refuted by experiment. This requires imagination. A trained scientist can accumulate experience in imagining certain situations, even subjecting his imagination to control, but this does not mean that he will automatically come up with the correct hypothesis (or any hypothesis at all, for that matter). A theory is not an arbitrary invention coming from nowhere any more than is a poem, a piece of music or an object of art. At this point the theory of knowledge confronts us with a false dichotomy: either something is devised anew, without antecedent, and in a capricious and arbitrary way, or it is discovered. That is, it was there all the time, constant and unchanging. This view is not consistent with modern science. Scientific method is not something that happens prior to science but arises from science.

Scientific method is the intellectual counterpart of reality-testing. We try out a suspected solution but if it fails we start at the last success and plan another experiment until we find a successful solution. Success is not always easy because the experiments have to be carried out under controlled conditions if the results are to be considered valid. Experimentation allows the scientist to pursue his hypothesis beyond the realm of everyday things. In order to do this, he may have to employ instruments, to isolate phenomena, to create artificial conditions in which the desired phenomena can happen, all in order to consummate his creative powers.

Types of Investigations Using the Scientific Method.

1. Experimentation. That is, the performance of an arranged systematic series of objective observations under controlled conditions which are repeatable and verifiable.

2. Naturalistic Observation. That is, the performance of observations of natural phenomena as they occur in nature without trying to influence the results, as in a field study.

3. Technological By-Product Accumulation. Research is designed to acquire knowledge for its own sake. Applied science fields, such as engineering, medicine, agriculture, etc., are primarily concerned with solving practical problems. In the solving of practical problems, data of interest to "pure" (or "conceptual") science may accumulate. For example, a physician may use a last resort technique on a hopeless case that aids the patient to regain his health. Such information is useful to the pure scientist and he may later explain the phenomenon.

NATURE OF SCIENCE

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TOPIC OUTLINE

I. Matter and the Universe

- A. General Introduction
- B. Concepts of the Universe
    - 1. Student objectives
    - 2. Structure of the Universe
    - 3. Composition of the Universe
- C. The Concept of Matter
    - 1. Matter is measurable
    - 2. States of matter
    - 3. Characteristics of matter
    - 4. Organic and inorganic matter
    - 5. Extra-material Things in the Universe
        - a) Concepts
        - b) Science and the extra-material universe

II. Observation and Hypothesis

- A. Formation
- B. Qualities of a good hypothesis
- C. The logical approaches to knowledge

III. Experimental Design

- A. Planning the Experiment
    - 1. The experimenter must ask himself what questions must be answered to provide enough information to make a judgment about the hypothesis?
        - a. What is normal (or usual)?
        - b. What factor does the hypothesis assume to be affecting the behavior or producing the phenomenon?
        - c. What instrumentation will be needed?
        - d. Which method of inductive reasoning would be asked to make a judgment about the effect of the treatment(s)?
            - 1) The method of agreement.
            - 2) The method of difference.
            - 3) The method of covariation.
            - 4) Residual variation.
        - e. Some experimental designs in common use.
            - 1) Progress followed to final time.
            - 2) Measurements made only at beginning and end.
            - 3) The Latin square.

B. Carrying Out the Experiment

  1. Assembly of the materials and equipment needed.

    a. In established laboratories.
    b. Scientific supply houses.
    c. Some experiments require special equipment.

  2. Planning the Time Requirements

    a. Dependence on the hypothesis.
    b. Chemical experiments.
    c. Biological experiments.

C. Knowledge and Wisdom Contrasted: How does the Scientist Use His Acquired Knowledge?

  1. Knowledge (Facts).
  2. Wisdom (Understanding the facts).

D. Kinds of Research

  1. Basic and applied research (difference not important).
  2. Difference between basic and applied research and Technology.

IV. Facts: How the Scientist evaluates data

A. Acceptable and Unacceptable Philosophies.

  1. Authoritarianism
  2. Intuitionalism
  3. Rationalism
  4. Empiricism

B. Collection of data.

V. Discussion and Summary: How Scientists Reason

A. Interpretation of results and drawing conclusions.

  1. Null Hypothesis
  2. Elements of Statistics

    a. Mean, standard deviation and standard error.
    b. Chi-Squared

  3. Inductive canons

B. Acceptance or rejection of the trial hypothesis.

C. Formulation of a new or successive hypothesis.

D. Summary

VI. Writing Scientific Reports

- A. Organization of a Scientific Report in Biology

- B. Biological Literature

    1. Introduction.
    2. How the Literature in Biology and Biochemistry is used.

VII. What is Science?

- A. Folklore

    1. Magic
    2. Astrology
    3. Alchemy

- B. Pseudo-sciences (Human Behavioral Studies)
  Economics, Political Science, Social Science, etc.

- C. Natural Sciences

    1. Physical Sciences
    2. Biological (Life) Sciences
    3. Interdisciplinary Studies: Biochemistry and Biophysics
    4. Applied Sciences
        - a. Biological: Agriculture, Medicine
        - b. Physical: Engineering, Other Technologies

    5. Technology

- D. Limitations of Science

- E. What is the Relationship of Science to Other Fields of Study?

- F. Why Study Science?

I. Matter and Universe

I. General Introduction

Some organisms are described as unicellular or acellular, e.g., amoeba. This is a result of two different observers perceiving the same organism and describing it differently. One observer views amoeba in all its analogies with different types of single cells. The other perceives its homology not with single cells, but with whole higher animals, i.e., it is more like a whole animal than an individual tissue cell. Thus, placing the stress on either the first or last term in 'unicellular animal' makes a difference. These observers saw the same thing but construed the evidence in different ways.

The approach might begin by asking the students to view an object, e.g., amoeba, paramecium, etc., under a microscope, on a film loop or something bigger on the table. Let the student write the description of what he has seen. (Some discrepancies will come up in the description as in the case above, even though they are observing the same object.) Let the students discuss the reasons for these discrepancies in perception. They may not know why, but we know. The disagreements arise because what one perceives is a product of the interaction between the object and the subject. When others can perceive the same objects in the same manner we assign it that property, e.g., a square box. This implies that our knowledge of that object presupposes some permanence in a given thing. When we can recognize different objects as particular objects our knowledge then presupposes that there is a permanence and sameness in these objects. Thus, the first or basic step in scientific analysis or method is the concept of observation. In order for us to investigate something we must have a prior notion of what we are going to investigate, i.e., specific observation is a prerequisite of an investigation. The observation does not, however, have to be direct as in the case of the object on the table, the object could be perceived by means of a microscope, meter, etc., i.e., through indirect means. Observations can be qualitative or quantitative, but, in either case, it must be able to stand when others repeat it, for it to be acceptable.

Approach: Show two solutions of same colour but different concentrations to the class. Allow the students to describe the intensity of the colours that they have observed. Let them determine how much darker the more concentrated solution is when compared with the lighter concentration. Then use an instrument like the Spectronic 20 spectrophotometer to determine the absorbance of the dye in both solutions. Alternately, serial dilutions can be made of the darker solution until the same coloration as the light solution is achieved. This is designed to show some form of correlation between the quantitative and qualitative versions of perception.

Statements of observations must be clear and distinct, i.e., impossible of double interpretation. "He is five feet tall" does not imply he is fat, or thin. It deals only with his height. The statement cannot be construed to mean he is approximately five feet tall, etc.

The universe provides a fertile environment for a variety of observations. All that one has to do is look at himself or the things around him. "Things around him" needs some clarification. Things in this case means concretized objects and not abstract things. Listing a few of these 'things' or objects by students should lead to the question of similarities and dissimilarities among the objects and the specific properties that individuals read into the objects. The words "read into" here implies that two people may perceive the same object as two different things. This arises from the interpretation of the sensations that they feel.

It should not be surprising to the students to find the passage in the burial prayer saying "Ashes to ashes and dust to dust". The depth of the meaning of this statement may not be implicit to students at the first glance. However, the statement seems to say that the flesh or body (tree, man, etc.) of living things are of the same material as the soil or dust. An in-depth discussion of this should go to establish the composition of matter of which the universe is composed. This discussion should be extrapolation, seek solutions to questions like structure and composition of the universe.

B. Concepts of the Universe

Some of the dominant observations about the universe can be enumerated by any student. The universe is overwhelming in "space and time". Man is but a tiny fraction among the components of the universe. As measurements reveal, the magnitude ranges from objects of less than an Angstrom size (an electron) through those of 10 cm. magnitudes (mice) to 10^{28} cm. the size of the known universe. Our knowledge of the universe has been greatly enhanced by the different efforts undertaken in science and the related fields. Through progress in our understanding of Biology, astronomy and technology man has been able to go to the moon. Since the moon is relatively close to the earth, compared with the stars in the galaxy, the journey to the moon points to how little we know of this vast universe. Thus, the size of man as a component of the universe and its evolution should not be over-emphasized.

The diversity of what constitutes our own earth, not to mention the entire universe, creates more challenges for observation than some of us realize.

There are certain properties seen in living and non-living objects. Perhaps, all things are different experessions of the same thing. The universe is that, then, of which all things are a part, the totality of things, that which shares commonality, a oneness.

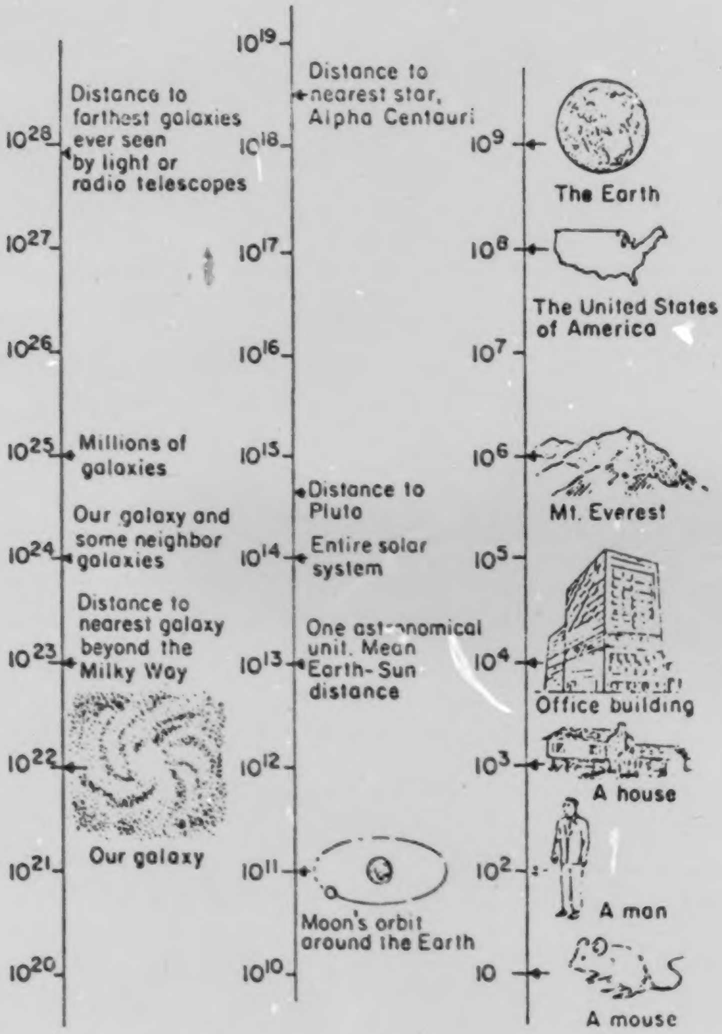
Four questions man has raised with the universe.

What is its structure?
What is its composition?
How old is it?
How did it come to be?

Answers to the four questions man has raised with the universe.

a. Answers from non-science fields.

Ref. Goolsby, C., 1970. Chapter 3, pp. 7-19.


10^28
Distance to farthest galaxies ever seen by light or radio telescopes
10^27
10^26
10^25
Millions of galaxies
Our galaxy and some neighbor galaxies
10^24
Distance to nearest galaxy beyond the Milky Way
10^23
10^22
Our galaxy
10^21
10^20
10^19
Distance to nearest star, Alpha Centauri
10^18
10^17
10^16
10^15
Distance to Pluto
10^14
Entire solar system
One astronomical unit. Mean Earth-Sun distance
10^13
10^12
10^11
Moon's orbit around the Earth
10^10
10^9
The Earth
10^8
The United States of America
10^7
10^6
Mt. Everest
10^5
10^4
Office building
10^3
A house
10^2
A man
10
A mouse

Scale of increasing magnitudes, from 10 cm. (size of a mouse) to 10^{28} cm. (size of the known universe.)

God and creation include the mystical nature of religion and ideas from the humanities, i.e., poetry which relates to the universe. None of these explain satisfactorally the nature of the universe. Some ideas in history are relevant, i.e., man is the center of the universe, the sun is the center of the universe, etc.

b. Answers from Science

1) Student Objectives

a) Becoming acquainted with functional information about our universe. The story of life in the universe cannot be fully told without reference to the life history of stars.

b) Developing functional concepts and understanding of the principles governing the universe.

c) Acquainting students with the wholeness of the universe and its relationship to man.

d) Acquainting students with the different kinds of matter composing the universe.

2) Structure of the Universe

There are 100 million or so galaxies in the Universe, according to astronomers. Each galaxy has about 100 million stars each. The sun is a medium-sized star in the Galaxy Milky Way. The genesis of galaxies appears to be that gases and cosmic dust accumulate in a location. It becomes irradiated by other stars, possibly by induced magnetic fields. The lighted mass begins to swirl about magnetic centers which draw material to it. This is counterbalanced by the centrifugal forces of swirling. New magnetic centers, cause eddies resulting in new stars, new planets about them and moons about the planets. The elements of the oldest part of the universe are calculated by Harold Urey and others to be 10 billion years old. Elements of the earth are about 4.5 billion years old.

3) Composition

The most abundant element in the Universe is also the simplest one, hydrogen. Hydrogen consists of a proton (or positive charge or alpha particle) and an electron (or negative charge).

Stars are thermonuclear fusion furnaces which generate other elements starting with hydrogen. The colors emitted by stars indicate the elements they contain. The same elements are found on earth and in the sun and other older stars. Six elements found in the sun but not naturally on earth have been generated in laboratory stars (cyclotrons). These are the last 6 elements of the periodic table.

Therefore, the Universe is not homogeneous in composition, but each star is capable of generating the elements, following the same rules man has discovered are at work on earth.

Discussion Question:

Some even maintain that the essential nature of the universe is spiritual. Do spiritual things differ from material things? Take a few minutes and write down the differences between material things and spiritual things.

C. The Concept of Matter

Specific Reference: Any freshman biology text.

Teacher Reference: Baker and Allen, (1965) Chapter 1 and 2.

One of the most widely accepted views of the universe is that it is material, that is, all things are composed of matter. Matter has been described as anything which has mass and occupies space. When we get into the laboratory, I want you to ask two questions of matter: (1) Can matter be measured? (2) Is all matter alike?

Not all men believe that all things are composed of matter. They hold that besides material things there are spiritual things in the universe.

1. Matter (or substance) is measurable. (Concept of mass weight and density.) Explain that gravitational force depends on the attraction of two masses; noting that weight may vary according to the force of gravitational attraction. The quantity of matter in an object is called its mass. The kilogram is the fundamental unit of mass. Mass is not necessarily related to size. Density is a measure of the amount of matter in a given volume of space. Thus, the greater the amount of mass in a certain space, the greater the density.

2. States of Matter. Matter exists in several forms. The three main states of matter are solid, liquid and gas. Matter can be made to change its form by raising or lowering the temperature or by varying the pressure. For example, heat applied to solid matter causes it to melt and vaporize; thus, changing it from liquid to a gaseous state. If gases or liquids lose heat, they pass to the solid state. The change in the state of matter represents a physical and a chemical change. These physical changes are the result of changes in the motion of atoms or molecules due to chemical bonding (See Teacher's Guide to Exercise 9).

Demonstration: States of Matter

A teacher should exhibit three closed test tubes, one each of sand, water and collected oxygen. He should then proceed to ask questions concerning the content of each tube, i.e. What have we here? How do these differ, etc? From this discussion the states of matter should be derived, (solid, liquid, gas). Introducing a glowing splint into the third test tube confirms the presence of oxygen.

Exhibit another large test tube three fourths filled with crushed ice.

Determine through student observation the change to water after a period of standing. Accelerate the change into the water by heating with a bunsen burner. Attach a balloon securely to the mouth of the test tube and continue to heat.

As the balloon enlarges, questions on this specific observation to establish still another change in the state of matter, solid to liquid to gas (water vapour) should be entertained.

Laboratory Exercise

Laboratory Activities for Biology, Ex. 2 -- Concept of Mass, Weight and Density.

3. The Characteristics of Matter. Considering some overall characteristics of matter we may establish three categories: elements, compounds and mixtures.

An element is matter made up of identical atoms. We know 103 elements today which are recognizable by certain characteristics. These characteristics or properties of the elements may be physical or chemical in nature. Physical properties include weight, texture, conductivity of heat or electricity and specific freezing and boiling points. Chemical properties refer to the way in which an element reacts chemically with itself or other elements.

Elements and their symbols most-used in this course include:

H	Hydrogen	I	Iodine	O	Oxygen
He	Helium	Fe	Iron	P	Phosphorus
Ca	Calcium	Mg	Magnesium	K	Potassium (Kallium)
C	Carbon	Hg	Mercury	Na	Sodium (Natrium)
Cl	Chlorine	N	Nitrogen	S	Sulfur

A compound is the product of chemical combination of two or more atoms. The basic unit of a compound is a molecule. The atoms in molecules are held together by chemical bonds. Thus, the building of molecules is dependent upon the formation of chemical bonds between atoms. An important energy factor is associated here which varies from one kind of bond to another.

Examples include:

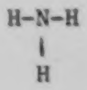
H_2 = H-H

O_2 = O=O

N_2 = N≡N

HCl = H-Cl

H_2O = H-O-H

NH_3 =

$\begin{array}{c}H-N-H\\ |\\ H\end{array}$

CH_3-COOH (Glycine)

$C_6H_{12}O_6$ (a hexose)

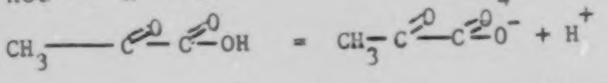
H_2CO_3

Ions. The number of electrons (negative (-) charges) orbiting the atomic nucleus is equal to the number of protons (or positive (+) charges) in the atomic nucleus. Such atoms are, therefore, electrostatically neutral. If the number of electrons exceeds the protons, then the charge will be negative (-) and the valence will be equal to the number of excess negative charges. If there are fewer electrons than protons, then the charge will be positive, the valence being equal to the number of protons in excess of the electrons. Generally, speaking, ions are the reactive forms of the elements, radicals and compounds.

Examples are:

$H_2O = H^+ + OH^-$ $\qquad$ $NaOH = Na^+ + OH^-$

$HC\ell = H^+ + C\ell^-$ $\qquad$ $KHPO_4 = K^+ + HPO^-_4$



$CH_3—C(=O)—C(=O)—OH = CH_3—C(=O)—C(=O)—O^- + H^+$

(pyruvic acid) (pyruvate ion) (hydrogen ion)

A mixture is composed of two or more substances not joined by chemical bonds, e.g., water and sand. Since many important parts of living cells exist in this state, mixtures are exceptionally important in biology. Living matter, in fact, is the most important complex mixture of all.

Demonstration: Mixtures and Compounds

A demonstration-discussion on mixtures vs. compounds (along with energy conversions may be carried out in the laboratory using the following:

a. Mixtures of elements--Fe and S and the mechanical separation of Fe filings from mixture using a magnet. (This may be done on overhead projector by pouring mixture on clear acetate sheet and projecting separation.)

b. A compound from two elements--Fe and S are gently heated in a pyrex test tube or deflagration spoon in a hood to form iron sulfide.

c. New compounds from chemical combination of other compounds--Discuss energy transformations involved when compound(s) form from the explosive combining of a drop of glycerol (glycerine), $C_3H_5(OH)_3$, and a teaspoon of potassium permanganate (a compound) in hood.

4. Organic and Inorganic Substances. Organic substances contain carbon atoms, except that the inorganic carbonates also contain carbon.

Atomic Structure and Other Topics Under Basic Properties of Matter key terms from student's specific reading on board as discussed, the overhead projector and commercially-or hand-prepared transparencies of diagramatic atom models may be used to begin a simplified discussion of:

a. atomic structure and sub-atomic particles.
b. bonding and the role of outermost or valence electrons in bonding

(1) ionic bonds (NaCl)
(2) covalent bonds (H_2O or CH_4)

(3) hydrogen bonds (attraction between individual water molecules)

c. valence and valence electrons.
d. oxidation and reduction, as they involve the loss or gain of electrons.

5. Are there extra-material things in the universe?

a. Concepts of the extra-material universe.

(1) In the Jewish, Christian and Mohammedan theology the universe was created by God, who is characterized as knowing all (omniscient) and being everywhere and in everything (ominpresent).

(2) We have no way of proving or disproving the presence of God because he cannot be weighed, measured, contained or excluded.

(3) Scientists base their explanations upon the natural laws, but they cannot explain, nor do they try to explain, what makes the natural laws work. Theologians would say that God makes the natural laws work.

(4) It has not been many years when it was believed that space was not empty, but filled up with a non-measurable material called the aether (ether). In fact, we still make allusions to radio waves travelling through the ether. Today, we know space is not empty.

(5) The mind is understood in folklore to be a personality which operates the brain. If a person is upset, we say "He is beside himself". If a person behaves in certain abnormal ways we say "He has lost his mind!" Psychologists generally avoid discussion of the mind and concentrate on behavior. Like God, the mind cannot be weighed, measured, contained or excluded by physical means, but there is no doubt among conscious people that it exists.

b. Science and the extra-material universe.

1) Nearly all religions offer explanations of awsome natural phenomena which makes it possible for man to experience them and still keep his sanity (or at least he does not suffer from great fear and anxiety about them). When scientists formulate scientific explanations based on repeatable experiments, these explanations become part of science. Example: The Serpent told Eve (in the Genesis story) that the fruit of the Tree of Knowledge would not kill her. She experimented and tasted it. She discovered that knowledge would not kill her (but in the process something of innocence was lost).

2) The study of Extra-sensory Perception (ESP) was admitted to the American Association for the Advancement of Science in 1969. ESP is also recognized in a number of universities as an area for scientific investigation even though it is a "pseudoscience".

Elizabeth D. Clark, of North Carolina A & T State University reports classroom discussion of Matter and the Universe.

In discussing the theories of the origin of the universe one student cited a theory that another planet or mass may have come close to the earth, attracted a part of the earth's mass, and disconnected the moon from the earth. The mass did not have enough gravity to exceed the pull of the earth so the moon was left hanging in the earth's gravitational field.

Student(s): Is there an area between the earth and the moon where gravity is zero?

Teacher: Let us check some authoritative writings on the moon to find out. If that is so, why is it that the moon does not float or move out into space? If a structure remained between the two gravities it could just float in that area without being powered, or without being drawn by either gravity. Could it mean that there is no gravity, or that opposing gravities are balanced ?

Student(s): If enough meteors come between the earth and the moon at one time could the attraction between the earth and the moon be broken and would it then float away?

Teacher: Anything is possible, but remember that meteors, the earth and the moon are moving at different rates and in different directions, most likely the break would never be complete or last for long. You will be taking physical science next semester and may find answers to all of your questions. If you wish to know now, you may find some answers in the National Geographic for May, 1969. You may be able to find some good material in the International Series of Monographs on Pure and Applied Biology, Modern Trends in Physiological Science. I have three copies in the library. If you are interested, later on, we may find someone to give a seminar on this topic.

It is said that the primitive atmosphere was most likely composed of what gases?

Student(s): CO_2, CH_4, H_2O, H_2, NH_3.

Teacher: Why do scientists accept this as a possibility? (there were no answers). At what point would a scientist accept a statement?

Student(s): After many experiments testing the possibility of the statement. But how can we test today what the primitive atmosphere was long ago?

We can start where we are today and back test.

Teacher: Can you explain that further?

Student(s): We can test for chemicals making up life and the atmosphere today and try to form living things from different combinations of these chemicals.

Man can not create life today.

No, but maybe he can synthesize some important chemicals in living tissues and some day maybe create life. We can certainly say that the chemicals in living tissue either existed in the primitive atmosphere or there were chemicals that could be transformed into the chemicals of living cells.

This is a good point on which we can start to do reading research. Some scientists believe that the present day volcanic gases give a general indication of the nature of the primitive atmosphere. These gases are composed mostly of water H_2O, CO_2, CO, HCl, HF, H_2S, N_2, NHCl and CH_4. I would like for you to read Miller's Experiment and Fox's experiment with reference to the primitive atmosphere and the origin of life. If you are interested in detailed discussion of the pros and cons of many such theories read the Pure and Applied Biology recommended above.

In order for us to understand and appreciate the chemical reactions postulated to have happened in the primitive atmosphere--we will have to study the atoms, their energies and their combining powers.

We then defined atoms, elements, molecules, compounds and mixtures. We discussed the structure and combining power of atoms, ions and ionization. Seven students made appointments to come in for personal help on the unit. Two students remained an extra hour the same day for discussion. We will spend this week on simple chemistry. Most students did not take chemistry before.

These discussions come up and last only a short period of time. I use a tape recorder when they begin to discuss material. Sometimes it sounds like "just talk", but after listening to it again some basic challenges are recognized. Students try to think things out on the spot. It is their reasoning behind the discussions that I enjoy. Most of the time they have not read but they find their need to read. When I first assigned the atom for study, one student said, "I don't like Biology and I'll never scratch Chemistry's head". After this discussion the same student said," I guess I do need to know something about the atom. I'll try but don't expect any big thing". "I'll work with you personally". She stayed an hour after class and returned with others the next day.

II. Observations and Hypotheses

Specific Reference:
Baker and Allen, 1968. Part I, Chapter 3, pages 17-38.
Goolsbv (1970) Chapter 1

Alternate References:
Villee, C., (1967, Chapter 1, pp. 1-7.
Baker and Allen, (1968a) Chapter 3, pages 27-48.

The person who is philosophically or psychologically oriented to perceive some unexplained event or phenomenon in nature or in the laboratory has his curiosity and his imagination aroused. This leads to the formulation of a trial hypothesis. For example, in 1928 Sir Alexander Fleming, while working in the bacteriological laboratories at St. Mary's Hospital, London, observed that a mold that accidentally contaminated a culture killed the bacteria near it. He hypothesized that the mold was secreting the agent that was killing the bacteria. Consequently, he cultured the mold in broth and tested the mold-free culture medium for its ability to kill various bacteria. The mold was identified as Penicillin notatum and the antibiotic it formed was named penicillin. At best Fleming considered penicillin as in annoyance in his cultures and stopped working with it in 1932. Seven years later when a better control of infections in war wounds was sought, Chain and Florey and their associates at Oxford resumed the study of the mold, succeeded in extracting and concentrating penicillin a thousand-fold and opened the way through animal experiments for the use of this wonderful drug in man. A change in philosophical orientation benefited mankind.

A. Formation of a hypothesis. A hypothesis is just an idea suggested by the phenomena observed. It is seldom written out but is formulated in the mind of the experimenter. A good hypothesis has these attributes:

It correlates facts or observations and in so doing

It forecasts other facts or occurrences, and

It allows for discrimination between valuable and worthless information generated by the experiment with regard to the particular hypothesis.

B. The qualities of a good hypothesis include these attributes:

It must be plausible.

It must be capable of proof and suggest practical means of doing so.

It must be adequate to explain the phenomenon to which it is applied

It must involve no contradictions.

Simple hypotheses are preferred to complex ones. An old rule known as "Occam's Razor" or the Law of Parsimony, says that if there are several possible explanations (hypotheses) for a phenomenon, the simplest one is most likely to be correct.

A hypothesis may be posed as a question to be answered, as a declarative statement of reason and intent, or as part of a reasoning sequence. A general form of the latter might read, "If (such and such fact be so) then (we might) expect), this result (that thus and thus is so). i.e., a logical step after the colligation of a variety of separately observed facts.

The logical approach to knowledge.

a. Induction - Inductive reasoning involves proceeding from specific instances to a more general one.

b. Deduction - Deductive reasoning involves going from the general to the specific.

Specific Reference:
Baker and Allen, Hypothesis, Prediction and Implication in Biology, Part I, Chapter 3, pages 17-38.

Alternate References:
Villee, C., Biology, Chapter 1, pp. 1-7.
Baker and Allen, A Course In Biology, Chapter 3, pages 27-48.

At this point the class should be introduced to Exercise 1, Scientific Method in Laboratory Activities for Biology and Teacher's Guide to Laboratory Activities for Biology.

Classroom Account by Robin M. Griffith, Norfolk State College

Each pair of students was given a plastic cylindrical bottle wrapped in tin foil and containing one of 30 possible objects. The following includes some student responses to the series of questions I asked about the box. In the beginning students did not know what kind of container it was, or even if it was a container, nor did I have representative objects, like those in their boxes, present. [T.: = teacher, S.: = student(s)]

T: Before touching it, can you say anything about the object in the box?

S: Dry ice
jumping beans
bottle with something inside
nothing
something dead (no air)

T: Now you may touch it. Record what you
(a) do to determine what's inside the box.
(b) think is in the box and why.

I wrote their answers on the board:
Smelling, shaking, random, rolling. Careful guesses abound but few references as to possible number of objects inside boxes, weight, or size. They mostly talked of shape based on its ability to roll or not.

T: Compare your box with those of others who had similar ideas about its contents. Does this change your idea?
Many ideas were changed. Initially sand and pebbles and beads were the most common answers. When they began to compare their boxes, however, and hear the differences they became braver in their guesses.

At this point I wheeled in a table of representative objects.

T: Without touching anything on the table do you see your object? How might you test your idea that your object is the same as the one you see on the table?

One student requested a scale, another a ruler, a third a duplicate and some tin foil to duplicate experimental conditions - (Later this led to a short discussion of the importance of instruments in scientific research).

Finally each pair of students had to commit themselves as to what was in their jar. Then they were allowed to open them.

Surprisingly, there were many wrong guesses. We talked of why. Some students felt that the tin foil blurred and changed the sound made by the objects and thus they were confused. Others suggested various tests to differentiate between objects.

Example: a) Testing the time it takes for the object to fall from the top to the bottom so as to measure size of object as compared to length of tube.

b) Various ways to roll the tube so as to distinguish between the sounds made by various shapes.

Questions on Hypothesis

Discussion Questions:

1. Is it common sense that the question should be asked about observable things and their activities in the universe?

2. Discuss the relationship between Hypothesis and Observation.

3. What is a continuation hypothesis?

Self-Test:

1. Why must a scientist be careful not to extend his experimental conclusions to organisms other than those with which he worked?

2. Why does the attainment of any absolute truth lie beyond the realm of science?

3. Review the steps of the scientific method, and discuss each of the steps. What is a "controlled experiment"?

4. What is the relation between an hypothesis and an experiment?

5. Devise an hypothesis for each of the following observations. Then outline an experiment to test your hypothesis.

   In mice of strain A, cancer develops in every animal living over 18 months. Mice of strain B do not develop cancer. However, if the young of each strain are switched immediately after birth, cancer does not develop in the switched strain-A animals, but does develop in the switched strain-B animals living over 18 months.

6. Can you think of observations or problems which have not been investigated scientifically? Try to determine in each case whether or not such investigations are inherently possible.

7. What factors have been responsible, to a large degree, for the explosion of biological knowledge in the past few years?

8. Why was Hooke's use of the microscope so significant?

9. Why is the 17th Century called the beginning of the "scientific revolution"?

Answers:

1. The conclusions based on the use of his experimental organisms may or may not apply to other groups.

2. Absolute truth carries with it a quality of being closed to contradictions.

For further experience with the scientific method have students do Exercise 1--The Black Box or Closed Box.

ANNOTATED OUTLINE

III. Experimental Design: How Does the Scientist Acquire His Knowledge?

It is the aim of this section to help the student understand some basic activities involved in the planning and performance of an experiment once an hypothesis has been formulated.

Approach: Object for Discussion

To introduce the discussion of this section prepare two pneumatic troughs each with a candle. Add 1% lime water to a sufficient depth (determined before class-time) to meet volume requirements for the use of oxygen. Place a beaker, or better, a bell jar, over one of the candles. When the contained oxygen in the jar is used, the flame will go out.

Ask the students to formulate hypotheses about this observed phenomenon. Select for testing the hypothesis that there is something in the air needed by burning candles.

1. Planning an Experiment

The experimenter must ask himself what questions must be answered in order to provide enough information to make a judgement about the hypothesis.

Induce students to ask the following questions and write them on the board so that they will know that they should be part of their notes.

a. What is normal or usual in this case? (Ans: The uncovered candle burns until it runs out of wax or is drowned.)

b. What sort of name could we give that candle?
(Ans: The normal, the reference, the base line, or the control.)

The teacher should have an easily read sign marked CONTROL which he places by the uncovered candle, and another sign, EXPERIMENTAL, which he places next to the covered candle.

c. What factor does the hypothesis assume is affecting the behavior of the flame? (Ans: Something in the air.)

d. What equipment do we need to test this factor?
(Ans: Very little else. A stop watch, maybe. See how long the candle burns. Relight it and when it seems to be approaching its limit, let in some more air. Time the period of air intake and see how long the flame burns.) There are also other ways that students will suggest.

There are four "canons of inductive reasoning" set forth by John Stuart Mill in the mid-19th Century. These should be reproduced before class and handed out at this time.

1) The method of agreement--where a condition is uniformly present, it may be assumed to be a probable cause.

2) The method of difference-when an event occurs with a specific condition present, and does not occur when it is absent, one may conclude that the condition was the cause of the happening.

3) The method of covariation--in which variation in a causal factor produces of a similar change in the results.

4) Residual variation where removal of a cause still leaves some effect, due probably to other causes not accounted for.

Ask which of these might be used finally to make a judgement about the observed phenomena. (Ans: Probably 1 and 2)

Then, we should arrange the tests so as to see easily if things will vary in this way.

1) We said above that there should be a group to show what would normally happen (The Control). The control is usually a group but in this case it is the normal air. The experimental material will be the spent air in the bell jar. The candle will only burn if the substance needed from the air is present.

2) If we are going to consider the method of covariance, what could we do with the covered candle? (Students will suggest various ways of getting more air into the jar when the candle flickers.)

e. Some Experimental Designs in Common Use

Here are some designs in common use. (These should be reproduced beforehand and handed out here.)

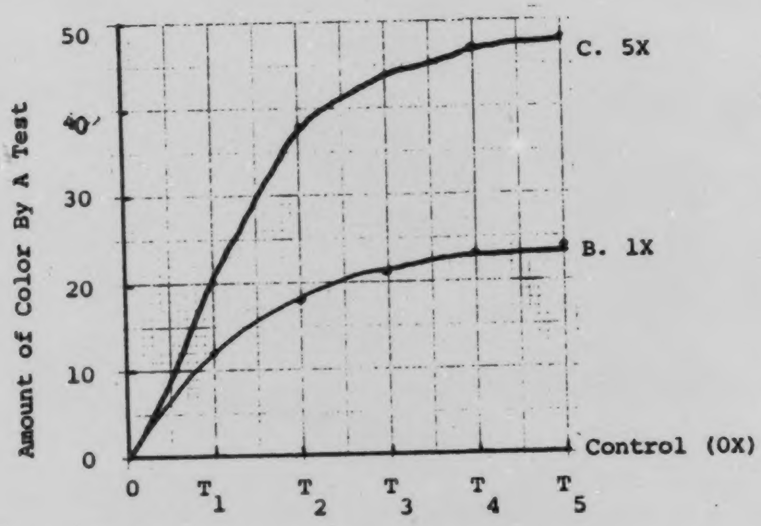
1) Progress followed to final time.

Amount of Color Produced by a Test

Time:	T_0	T_1	T_2	T_3	T_4	T_5
Treatment						
A. Control (OX)	0	0	0	0	0	0
B. Quantity (IX)	0	12	18	21	23	24
C. Quantity (5X)	0	20	38	44	47	48

X = a given amount of material (substrate)

We may represent such results by using a graph, viz:

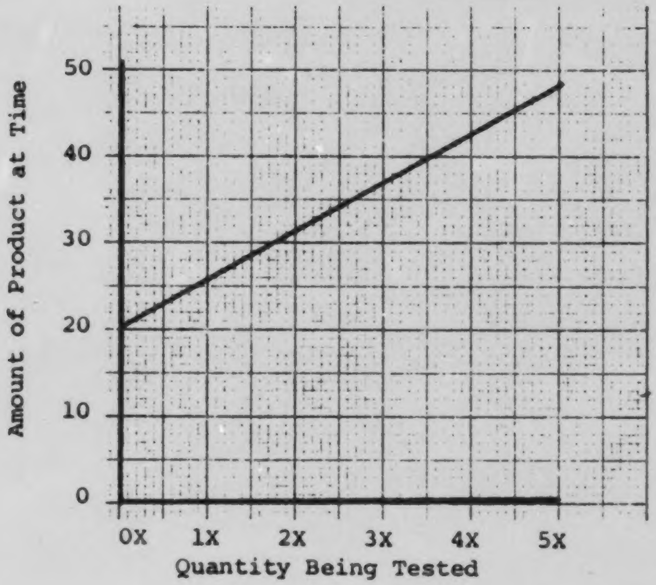


2) Measurement made only at beginning and end.

Another design makes use of only two times, the start (T_0) and the end (T_1).

Group	Quantity Being Tested	Amount of Product at Time
A Control	0X	20
B	1X	26
C	2X	31
D	3X	37
E	4X	43
F	5X	48

X = a given amount of material

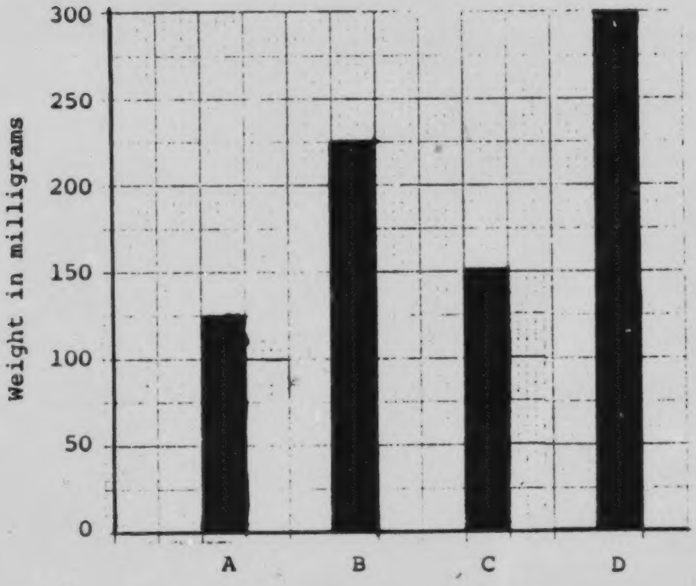


3) The Latin Square.

The latin square design compares the effect of two treatments (sometimes more) when given separately and when given together. This design makes use of the canon of difference. It is basically a combination of a control and three test groups.

Group	Treatment	Organ Weights in mg. After Time T
A (Control)	None	125
B	1 mg. of S	225
C	1 mg. of R	150
D	1 mg. of S plus 1 mg. of R	300

This sort of design is represented graphically by a histogram.



B. Carrying Out The Experiment

1. Assembly of the Material and Equipment Needed.

a. In established laboratories all, or most, of the equipment and materials needed will be on hand for the kinds of experiments that the laboratory specializes in.

To begin with the probable experience of the students, ask in what ways and why do student chemistry laboratories differ from anatomy laboratories? from physiological laboratories? from biochemistry laboratories?

b. Scientific Supply Houses

The teacher should present for student examination one or more catalogues listing scientific materials. Students should be able to conclude after a brief examination that many manufacturers use the scientific company as a supply depot for laboratories.

Find an opportunity to point out that the Food and Drug Administration does not permit supply houses to sell dangerous chemicals, drugs, or equipment to lay individuals.

c. Some experiments require special equipment to save time, provide detection or recording of the phenomena, behavior, etc. Many experiments like the candle experiment (above) require only the simplest equipment but sharp wits or careful observation.

2. Planning the Time Requirements

a. This depends upon the hypothesis. An hypothesis that is very broad may take a lifetime of experiments (and perhaps also a large team of scientists and technicians.) Individual investigators choose hypotheses narrow enough to be tested in the time available.

b. Chemical experiments may be interrupted and started again, as a rule.

c. Biological materials do not stop or go for the convenience of men. Injections and observations may have to be done at night and on weekends. Plan to end the experiment at a convenient time on a convenient day.

C. Knowledge and Wisdom Contrasted

1. Knowledge

Knowing has been discussed under the section on Facts. Facts are compiled in treatises, manuals, books of tables, etc., and many facts are held in the memory of scientists.

2. Wisdom

Wisdom involves understanding the facts so as to make good interpretations and predictions. This will be taken up in the section on Discussion.

3. Evaluation of the Data

The facts presented by the experiment must be evaluated in order to arrive at understanding about them. Statistics is a mathematical procedure used by the scientist to help make decisions about small differences.

D. Kinds of Research: How Does the Scientist Use His Acquired Knowledge?

All scientific research makes use of the scientific method. It is not important to distinguish between basic and applied research (the difference being merely the kind of problem investigated, not a difference in procedure.) However, the educated person should know the difference between these two, (basic and applied science) and the services and production (usually for commercial purposes) we term technology (See also Section VIII).

1. Basic and Applied Research

It has been a basic tenet in universities that scientists be given the opportunity to research their ideas in what ever field they felt inclined to do so. This has led to much wider variety of investigations than if all researchers in a department had to investigate phases of the same problem. When the topic under research seems to have a highly specialized use, or no apparent use, we refer to it as "basic". Examples of basic research include much of the work done in nucleic acids in the last two decades, the recently renewed interest in the structure of water, and the metabolism of cells.

Applied research concerns itself with the solution of practical problems of man's day to day needs. Examples would include plastics and adhesives chemistry, metallurgy, medical bacteriology, parasitology, agronomy, animal husbandry, oil-well and other types of prospecting. In general, medical and health science, engineering, and agriculture in its various branches are included.

A scientist may start out to solve an applied science problem only to find in the end that he has to attack the project from the position of finding out a lot of basic information. A basic scientist may start out investigating a basic problem, only to find he needs some information generated by applied scientists. A virologist studying a non-infectious virus is doing basic research, a virologist studying a cure for hoof and mouth disease virus is referred to as an applied scientist.

2. Technology

Perhaps the biggest difference between science and technology is that scientists are always asking "Why?". Technologists are not interested in why except in order to sell the goods or services involved. Even then, their information is frequently sketchy and used more to make people feel socially unacceptable if they don't buy or use their product or service. For example, an X-ray technician may need only to know how to operate the machine, someone has already determined what the settings should be (applied research) and the resultant picture is evaluated by him in terms of the excellence of its clarity--the interpretation is the job of the physician (who may be either a basic or applied scientist), depending upon his attitude.

3) We still don't know what gravity, electricity, or the living state is. We do know how these things behave and thus we are able to use them for our needs. We know that sodium gives a yellow color in a hot flame in the laboratory and also that the same color is seen in the light of many distant stars, because the same laws are acting everywhere as though sustained by God (as Creator, the Intelligence, the Ominiscience, or as Nature).

Questions on Matter and the Universe: For discussion.

1. What is the universe?
2. Discuss the origin of the Universe.
3. How may a sample of the moon's surface change our theories and concepts of the universe?
4. Is the mere existence of the universe science or is science the result of man's effort to understand the universe?
5. Discuss the composition of the universe.
6. Discuss Matter and its composition.

Self-Test:

1. What are the three general forms of matter?
2. Distinguish between the three forms of matter.
3. Distinguish between a physical change and a chemical change.
4. What is the most accurate method used in determining the age of the earth?
5. Distinguish between animate and inanimate matter.
6. Discuss the aims and the limitations of science?

Answers to Self-Test:

1. Solid, liquid, and gas.
2. a. Solids have definite shape and definite volume; b. liquids have definite volume, but no definite shape; c. gases have neither definite volume

3. Physical changes do not alter the composition of matter. Chemical changes result in the formation of new substances with new properties.

4. The method using radioactive actino-uranium (Uranium^{235}) with a half-life of 7.13×10^8 (713,000,000) years.

5. Animate matter exhibits the characteristics of living things whereas inanimate matter does not exhibit the characteristic of living things.

6. a. To make and use theories; b. observing, problem-posing, hypothesizing, experimenting, and theorizing is both the beginning and the ending of science.

Approach

To introduce the ideas in Section D, use this story or some other:

Alexander Fleming noticed that a mold growing in his bacterial culture plates was killing his bacteria. He worked from 1928 until 1932 on the extraction of penicillin. He was doing basic research. When World War II started in Europe, a better control of Staphylococcus infections was sought, so that Chain and Florey began to look for better strains of penicillium and to extract and concentrate the product into one useful in medicine (applied research). Once the procedure was determined, penicillin was grown in 50,000 gallon tanks by pharmaceutical houses, extracted concentrated, bottled and prepared for market (Technology at work).

Do not spend a lot of time on this section.

When the concepts of basic, applied science and technology are somewhat defined, then project a series of pictures depicting activities in a basic research laboratory and in various areas of the applied sciences. Have the students identify the projected view, scientific areas involved, and indicate whether basic, applied, science, or technology is being done. Here are some examples:

Slide	Code	Topic
1	1	Research chemist working in a university laboratory
2	1,2	Microbiologist preparing cultures.
3	1,2,3.	Physicist operating a nuclear accelerator
4	1,2,3	Artificial satellite aloft
5	3	Transistor radio
6	1,2	Geologist analysing ore samples
7	1,2,3	Atomic bomb exploding
8	1,2	Surgeon performing an operation
9	3	X-ray technologist with positioned patient
10	1,2,3	Nurse administering an injection
11	1,2,3	Physician examining a patient
12	3	Factory or farm

Code: 1--Basic research, 2--Applied research, 3--Technology

3. Use of the Microscope

Special References:

Lenkoff, E. S., 1967. Tools of Biology. Current Concepts in Biology Series. New York. The MacMillan Company.

Gray, Peter., 1967. The Use of the Microscope: Introductory Handbook for Biologists. New York. McGraw Hill Book Company.

Simpson, G. G., and W. S. Beck., 1969., pp. 546.

One of more of the following films may be used:

"How to Use the Microscope"(filmstrip). Carolina Biological Supply.
"The microscope". 11 min. McGraw Hill.
"Compound Microscope".10 min. Bausch & Lomb. (free)
Ealing film loop #81-0879--Microscopic Techniques.
Reports on teaching with a microscope. Evolution of the Microscope.
American Optical Co., Public Relations Department, AO.

Microscope: Its Applications. Leitz Opticals.

The Theory of the Microscope. Bausch & Lomb Optical Company.

For this section do Exercise 4--The Microscope and Microscopy, in the manual Laboratory Activities for Biology.

Modern tools and techniques used in cell study have grown out of advancements in other areas of science and technology. Equally important in this regard has been the active desire on the part of biologists to better understand all aspects of cellular structure and function.

a. Microscopy is the art of using the microscope to magnify objects which are too small to be seen with the unaided eye.

1) Light microscopes employ beams of light in magnifying objects. The following includes most of the types of light microscopes which the student might use:

a) Compound microscopes consist of two sets of lenses; an objective lens set mounted at one end of the microscope and the ocular lens or the eyepiece mounted at the other end. Magnification occurs in two stages: the objective first forms a real, inverted, and magnified image of the object; the ocular lens then further magnifies this image.

b) A stereoscopic microscope is a type of binocular microscope. The image produced is erect (right side up) and truly stereoscopic because the dimension of depth is presented.

c) The phase - contrast microscope is based on an optical technique which involves the action of the specimen on light and allows the specimen to be clearly visible. The principle employed is based on difference in behavior of light when objects of different densities diffract light.

2) The electron microscope utilizes a stream of electrons analogues to the beams of light employed by the light microscope.

b) Histological technique is the art or science of preparing organs, tissues, or tissue components for study and observation with the microscope.

Discussion Questions:

1. What is the role of microscope in modern scientific development?

2. Why might one think that the development of the microscope was one of the most important single contributions ever made to the advancement of biological research?

Answer 1. The microscope opened a new world of biology. No longer is the scientist limited to what his unaided eye could see. The intricate structure of tissue, the details of cells, as well as bacteria, protozoa, and parasites that were previously unknown all become visible under the microscope. The micorscope gave birth to the study of cytology, bacteriology, histology, mycology, embryology, and parasitology.

Answer 2. One class of instruments in the biologist's arsenal of tools stands alone--the microscope. It may be considered as the tool which has contributed most to the advancement of biological research. The compound light microscope is found and used in every biological laboratory. In recent years, the electron microscope has opened new fields of research and revolutionized older ones.

Self-Test on the Microscope

1. The microscope is an instrument which helps us
   - a. to see distant objects.
   - b. to see a magnified view of a small object.
   - c. to see a clear, smaller image.
   - d. None of the above.

2. The microscope should be handled
   - a. with one hand.
   - b. with one hand on the arm and other on the base.
   - c. with one hand on the base.

3. A good practice in looking through the microscope is
   - a. to keep both eyes open.
   - b. to keep one eye closed.
   - c. to keep winking.
   - d. to keep both eyes closed.

4. The student microscope must be placed on the desk with the
   - a. arm away from you.
   - b. arm towards you and in an upright position.
   - c. arm tilted.
   - d. arm on the side.

5. If the objective and eyepiece lenses are dirty they must be cleaned with
   - a. finger tips.
   - b. paper napkin.
   - c. lens paper.
   - d. cloth piece.

6. The concave side of the mirror is used
   - a. at all times in every microscope.
   - b. at all times on microscopes not equipped with condenser system below the eyepiece.
   - c. at all times on microscopes with a condenser.
   - d. on cloudy days only.

7. While using the high power, the adjustment should be made by
   - a. rotating the coarse adjustment knob.
   - b. pulling the tube downwards.
   - c. rotating the fine adjustment knob.
   - d. raising the body tube.

8. The high power of the microscope should be used
   - a. after the material has been viewed under low power and brought in the center of the field.
   - b. directly without viewing under low power first.

9. If you wear glasses, it is desirable to keep them on while using the microscope if you have
    a. short-sightedness.
    b. myopia.
    c. far-sightedness.
    d. astigmatism.

10. Looking at fresh material in a drop of fluid on the slide under high power should be done
    a. by putting a coverslip on the material.
    b. without a coverslip.
    c. with or without a coverslip.
    d. None of the above.

11. The total magnification of the microscope may be calculated by
    a. dividing the magnification of the objective by that of the eyepiece.
    b. multiplying the magnification of objective and eyepiece.
    c. noting the magnification of the objective.
    d. noting the magnification of the eyepiece.

12. If you move a slide with the letter "e" on the stage from side to side and view the letter through the eyepiece, the letter seems to move
    a. the way the slide is moving..
    b. in the opposite direction.
    c. from front to back.
    d. from back to front.

13. The image produced by a stereoscopic dissecting microscope is
    a. upside down.
    b. erect, right side up.
    c. inverted.
    d. false.

Answers:

1. b
2. b
3. a
4. b
5. c
6. b
7. c
8. a
9. d
10. a
11. b
12. b
13. b

IV. Facts: How the Scientist Evaluates Data

A. Acceptable and Unacceptable Philosophies

Three philosophical approaches to gaining knowledge are rejected by the scientist. These are authoritarianism, intuitionalism, and rationalism.

1. Authoritarianism proposes unquestioning belief in and obedience to authority. According to this point of view, one does not seek to discover new knowledge, but accepts the opinions of important people because they are important. This does not mean that the opinion of an authority in a subject of study is not respected and considered worthwhile, for such an opinion would be based on knowledge. However, when a scientist gives an opinion he expects that eventually the idea will be put to the test in a thorough experiment. This is in contrast with authoritarianism where, for example, a mayor may be asked the cause of yellow fever. His opinion on the matter would not be considered as good as the view of a governor or a king. If there were any discrepancy between opinion and observed fact, the observation would be rejected in favor of the opinion.

2. Intuitionalism gives precedence to one's emotions about an observation, when in spite of observation, one feels it, perhaps "in his bones," that the observation is wrong. The scientist, drawing on his knowledge and experience, may make a guess (hypothesis) about the cause of an observed phenomenon, but he is willing to subject such a hypothesis to rigorous testing.

3. Rationalism is a philosophy whereby one rationalizes the cause of of an observed phenomenon. For example, one may rationalize that since bats fly they must be birds. In the United States, white people have often rationalized their treatment of Blacks as being "proper because . . ."

   Some phenomena may appear to be very similar but have very different causes. It is not scientific to rationalize that they have the same causes until experiment has shown that to be so.

4. Empiricism is the philosophical doctrine that proposes that knowing is the result of first-hand, direct, original observations. It, therefore, relies upon observation and experimentation. Through empiricism, science has become a knowledge-generating activity that is continuous, creative and cumulative.

Reference: Lachman, 1956

B. The Collection of Data.

Personal care must be taken not to make blunders, such as recording a reading in the wrong place, putting down the wrong decimal relationship, or losing track of which objects received which treatment. Many errors are controllable. That is, those errors arising out of the use of faulty weights or measuring devices, a mistake in computations, such as the area, volume, etc., variations in the quantities of products formed, used, or wasted, and variation due to a residuum from prior treatments.

Errors which are seldom controlled are those that arise out of the individual variations to be found in animals and plants, and irregularities in the environment (such as differences in soil, temperature, or culture medium.)

We have mentioned above that chance errors tend to distribute themselves whereas systematic errors tend to accumulate. To test the validity of data it may be subjected to a test for "goodness of fit" but to test the variation we determine such statistics as the "standard deviation" and the "standard error".

V. Discussion and Summary: How Scientists Reason

Reference: Ingle, 1958.

A. The interpretation of results and drawing conclusions.

1. The Null Hypothesis. The null hypothesis assumes that the only differences from an expected value have been produced by chance. It is against this hypothesis that experimental data is tested. Since it is very improbable that any two real values would be exactly the same, one must decide how much variation should be permitted before the null hypothesis would be rejected and the acceptance of another hypothesis that a true, worthwhile difference in any given direction has been produced by the experimental treatment. This hypothesis, which was suggested by Fisher in 1917, then makes the basic assumption that there is no difference between treatments in an experiment. However, it cannot be proven that all are the same, but it can be shown that they are not.

2. Elements of Statistics. Statistics deal with the probability of an event happening. Scientists really never state their reports as being absolute, but compute the probability of an event happening again under similar circumstances. A 50-50 chance indicates great uncertainty about the conclusions. A 1 to 99 chance indicates great confidence that the event will happen again (or not happen again) under similar circumstances.

Common statistics and their symbols are:

The individuals datum, or variate, indicated by X,
The number of individuals in the sample is designated by n,
The sum or total, indicated by the Greek Σ or more simply by S,

The mean, or average is designated by $\bar{x}$. $\bar{x} = SX/n$

The deviation, d, is the difference between the mean and the variate, viz: $d = X - \bar{x}$.

The standard deviation, s, indicates how far from the mean about 2/3 (actually 68%) of the values lie. A value of $2s$ indicates how 95% of the values are distributed about the mean, and $3s$ indicates the way in which 99% of the values are distributed about the mean.

Most often the mean value for variates is given for a group and the statistic, standard error of the mean difference, or simply standard error, tells how much deviation from the reported mean another experimentor, doing the same experiment, might expect to come to the reported mean value. The symbol is $s\bar{x}$

Degrees of freedom (d.f). If four numbers equal 16, then three of them can be any number, but the value of the fourth is fixed if the sum is to be 16. The degrees of freedom for any single group of numbers that equal a given sum, therefore, is the number of items minus one (n-1). In computing the variance (s^2) the degrees of freedom (n-1) is used if the sample size is less than 6o individuals. Larger samples use the statistic N for the number and ignore the degrees of freedom.

Computing the Standard Deviation and the Standard Error.

These kinds of statistics apply only to measurement data and not to qualitative data (such as the number of green vs. the number of albino seedlings). Let us suppose that the amount of water in three samples of potato slices is 77%, 73% and 75%. Calculate the mean, standard deviation and the standard error for this data.

	Variates X	Deviation d	Deviation squared
	77	2	4
	73	-2	4
	75	0	0
SX	225	0	8 = Sd^2 (sum of squares)
$\bar{x}$	75		

The variance = $Sd^2/(n-1) = 8/2 = 4.0 = S^2$

The standard deviation = $s = \sqrt{s^2} = \sqrt{4} = 2.0$

The standard error, $s_{\bar{x}} = \sqrt{s^2/n} = \sqrt{4/3} = \sqrt{1.33} = 1.15$

These statistics are then expressed as the mean ± the standard deviation (s.d.), or as the mean ± the standard error (s.e.).

It is important to know what the standard deviation and the standard error refer to so that one can properly evaluate the data in many scientific papers.

mean ± s.d. = 75 ± 2.0

mean ± s.e. = 75 ± 1.15

Chi-Squared

For qualitative data, the goodness of fit is the appropriate measure to calculate by the following formula:

$$\frac{(\text{observed minus excepted})^2}{\text{expected}} = \text{Chi}^2$$

The expected is usually taken as the mean value for the number of observations made.

THE CHI-SQUARE DISTRIBUTION (VALUES OF χ^2_α)*

d.f.	$\chi^2_{.995}$	$\chi^2_{.99}$	$\chi^2_{.975}$	$\chi^2_{.95}$	$\chi^2_{.05}$	$\chi^2_{.025}$	$\chi^2_{.01}$	$\chi^2_{.005}$	d.f.
1	.0000393	.000157	.000982	.00393	3.841	5.024	6.635	7.879	1
2	.0100	.0201	.0506	.103	5.991	7.378	9.210	10.597	2
3	.0717	.115	.216	.352	7.815	9.348	11.345	12.838	3
4	.207	.297	.484	.711	9.488	11.143	13.277	14.860	4
5	.412	.554	.831	1.145	11.070	12.832	15.086	16.750	5
6	.676	.872	1.237	1.635	12.592	14.449	16.812	18.548	6
7	.989	1.239	1.690	2.167	14.067	16.013	18.475	20.278	7
8	1.344	1.646	2.180	2.733	15.507	17.535	20.090	21.955	8
9	1.735	2.088	2.700	3.325	16.919	19.023	21.666	23.589	9
10	2.156	2.558	3.247	3.940	18.307	20.483	23.209	25.188	10
11	2.603	3.053	3.816	4.575	19.675	21.920	24.725	26.757	11
12	3.074	3.571	4.404	5.226	21.026	23.337	26.217	28.300	12
13	3.565	4.107	5.009	5.892	22.362	24.736	27.688	29.819	13
14	4.075	4.660	5.629	6.571	23.685	26.119	29.141	31.319	14
15	4.601	5.229	6.262	7.261	24.996	27.488	30.578	32.801	15
16	5.142	5.812	6.908	7.962	26.296	28.845	32.000	34.267	16
17	5.697	6.408	7.564	8.672	27.587	30.191	33.409	35.718	17
18	6.265	7.015	8.231	9.390	28.869	31.526	34.805	37.156	18
19	6.844	7.633	8.907	10.117	30.144	32.852	36.191	38.582	19
20	7.434	8.260	9.591	10.851	31.410	34.170	37.566	39.997	20
21	8.034	8.897	10.283	11.591	32.671	35.479	38.932	41.401	21
22	8.643	9.542	10.982	12.338	33.924	36.781	40.289	42.796	22
23	9.260	10.196	11.689	13.091	35.172	38.076	41.638	44.181	23
24	9.886	10.856	12.401	13.848	36.415	39.364	42.980	45.558	24
25	10.520	11.524	13.120	14.611	37.652	40.646	44.314	46.928	25
26	11.160	12.198	13.844	15.379	38.885	41.923	45.642	48.290	26
27	11.808	12.879	14.573	16.151	40.113	43.194	46.963	49.645	27
28	12.461	13.565	15.308	16.928	41.337	44.461	48.278	50.993	28
29	13.121	14.256	16.047	17.708	42.557	45.722	49.588	52.336	29
30	13.787	14.953	16.791	18.493	43.773	46.979	50.892	53.672	30

* This table is based on Table 8 of *Biometrika Tables for Statisticians, Volume I*, by permission of the *Biometrika* trustees.

3. The Inductive Cannons. The search for the cause of any phenomenon may proceed according to the modified cannons of the inductive method, first proposed by J. S. Mill. They are:

a. The method of agreement--where a condition is uniformly present, it may be assumed to be a probable cause.

b. The method of difference--when an event occurs with a specific condition present, and does not occur when it is absent, one may conclude that the condition was the cause of the happening.

c. The method of covariation--in which variation in a causal factor produces a similar change in the results.

d. Residual variation where removal of a cause still leaves some effect, due probably to other causes not accounted for.

B. Acceptance or rejection of the trial hypothesis. This is an intellectual function.

C. Formulation of a new or successive hypothesis.

D. Summary - a restatement of the hypothesis and a concise listing of the results followed by conclusions reached in the discussion.

At this time it should be emphasized how Flemming's conclusion explained the data he observed in the contaminated plate and how the experiments he performed substantiated his hypothesis that the mold produced the anti-biotic. Another important aspect of the scientific method and discovery is also revealed in the Flemming story. Namely, that the usefulness of a discovery is not always immediately realized. The usefulness of Flemming's discovery was to await the work of Chain and Florey and their associates in 1939. Chain and Florey were able to make a continuation hypothesis from Flemming's conclusion. It could be stated as follows:

IF the mold, *Penicillium*, produces a substance, penicillin, which inhibits pathogenic bacteria in growing cultures, *THEN* it should inhibit pathogenic bacteria in live laboratory animals as well. This hypothesis was confirmed by experiment.

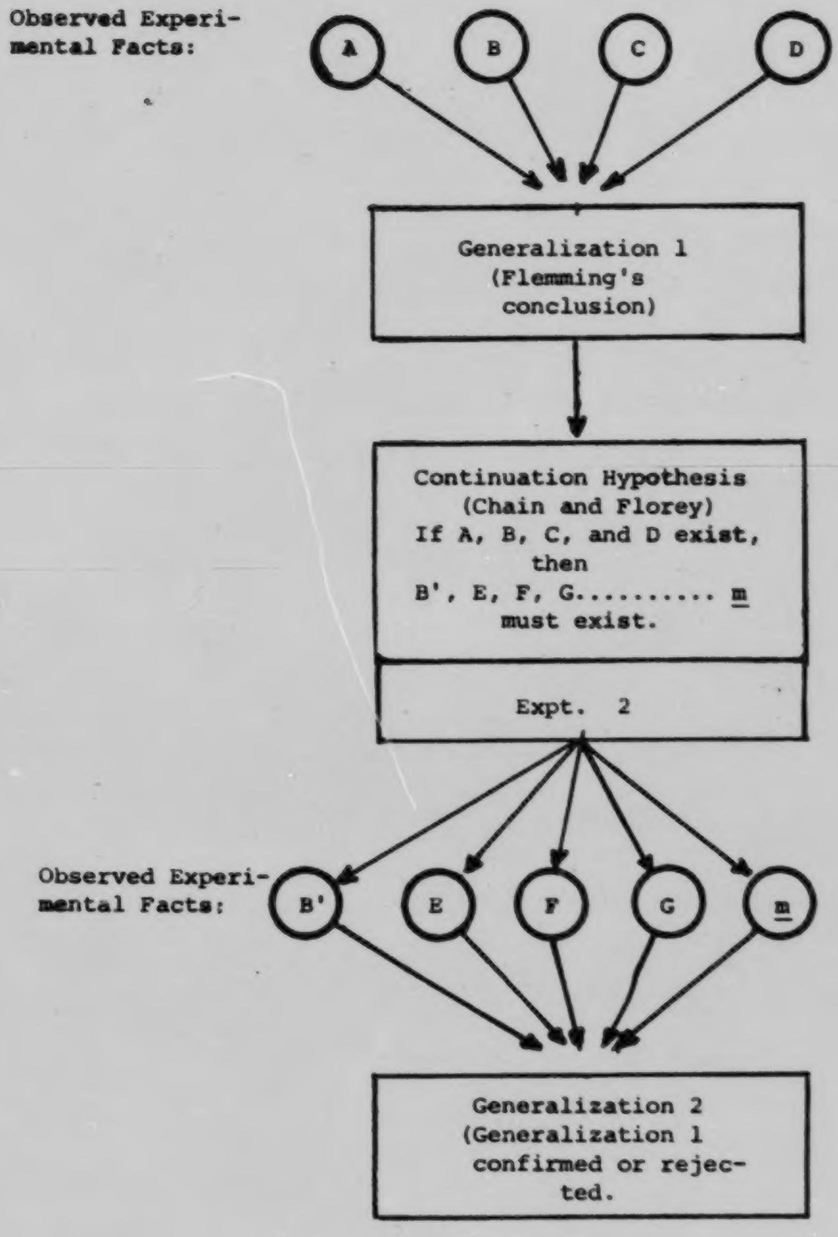

Observed Experimental Facts:
A
B
C
D
Generalization 1 (Flemming's conclusion)
Continuation Hypothesis (Chain and Florey) If A, B, C, and D exist, then B', E, F, G.......... m must exist.
Expt. 2
Observed Experimental Facts:
B'
E
F
G
m
Generalization 2 (Generalization 1 confirmed or rejected.

Figure 2

Approach:

Some time must be spent to detail the diagram above and terminology. By this time most students will have a fairly good idea of what a fact and a generalization are as well as a rough notion of how they are interrelated. Tell the class at this point that you have some culture plates (a slide works just as well) with two organisms growing inside for them to examine. One must provide some background information that Alexander Flemming saw a similarly contaminated plate while working in the bacteriological laboratories at St. Mary's Hospital, London, in 1928.

Materials:

1. Four to six agar petri dishes that were inoculated 48 hours earlier with Penicillium notatum and Bacillus subtilis and which show a pronounced zone of inhibition surrounding the mold, should be presented to the class, or

2. A slide of Penicillin notatum growing on a culture of bacteria can be projected.

Many of the following observations will be noted by the students.

a. there are colonies of bacteria growing towards the outside of the plate.

b. the bacteria are colored differently from the mold.

c. the bacteria are microscopic, the mold is much larger.

d. the mold is thread like.

e. most important of all, a clear zone, in which there are no bacteria growing, surrounds the mold.

Let the students suggest different reasons to account for the clear zone surrounding the mold and let them examine these reasons.

Most will be dismissed as not plausible and eliminated quickly. Following are some typical student conclusions:

1) the mold caused the zone.
2) the bacteria caused the zone.
3) the zone just occurred.
4) something from the bacteria caused the zone.

If e. (above) is the best reason then an important consideration concerns what is the "something" from the mold? This leads to the need for more experimentation in the testing of a continuation hypothesis (See diagram). The instructor may now explain to the class that Flemming's observations led him to ask the same question: "Did the mold produce a chemical substance that inhibited bacterial growth?" Consequently, he performed other experiments and found such a substance, confirming his continuation hypotheses. The mold was identified as Penicillin notatum and the antibiotic it produced was given the name penicillin.

Irene R. Clark of Florida A & M university suggests the following game for drawing conclusions:

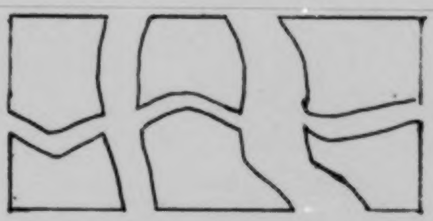
Objective of the Game:

To use a game atmosphere as a springboard for a discussion on important aspects of the nature of evidence.

Procedure:

Divide the class into two equal groups. Have each group separate and seated in different areas of the room near an overhead projector.

In each group have 4 students each cut-up (free handed) one index card into 3 or more pieces as shown in the figure below, or use pieces of a jigsaw puzzle.



Each of these 4 students in each group will place the total of 12 (4 x 3) fragments in a container where the pieces are well mixed. Distribute at random one fragment to each student in each group until all 12 pieces have been handed out. Turn on the overhead projector.

Now have one person volunteer to bring his or her fragment and place it on the lighted overhead projector. Students should remain seated unless they suspect that their fragment might fit. They should explain why they think it fits. From looking at the projected images, have students attempt to reassemble the 4 original index cards or the puzzle (one at a time) from the fragments. The object is to see which group can most rapidly reconstruct the original 4 cards.

This should lead into a discussion of the nature of evidence and how, in drawing general conclusion inductively, evidences from various sources must be fitted together in a logical fashion in order to reconstruct a total picture.

Martin J. Carey at Clark College reports the following conversation in connection with this approach to fact analysis.

I began the class by distributing several culture dishes with Penicillin notatum growing on a seeded bacterial surface.)

Instructor: I want you to carefully examine these plates. Let's list on the board every observation that you can make.

Student A: What is that fuzzy stuffy growing in the dish?

Instructor: Now remember, you are to provide your observations -- not ask me what is on the plate. Can you describe the fuzzy stuff?

Student A: O. K. It looks like the stuff that spoils old bread or uncovered jelly -- some kind of germ-- I dont' know what it is called.

Instructor: That's correct. It is called fungi. Have you ever noticed it growing in damp places -- such as on your shoes in a dark, moist closet or on the walls in a shower stall?

(Class responds in concert confirming having seen it before.)

Instructor: What else do you see?

Student B: There is something else growing on the plates -- or at least something else is on the plate.

Instructor: Yes, this is correct. Describe what you see.

Student B: I don't know how to describe it. It looks like a yellowish film or scum with a clear area.

Instructor: At this point I want to pass out these. These are called petri dishes for you to look at. In them is a substance called nutrient agar which is used to grow microorganisms on. Of course there is nothing growing on these. Compare these with those that have fungi and bacteria growing on them.

(Several hands are raised)

Student C: Bacteria? Is that what the yellow stuff is?

Instructor: Yes.

(The instructor now takes time to explain how microorganisms are cultured)

Instructor: (Pointing to list of observations on the board) We have now described everything on the plates -- or have we?

Student C: Why is the ring around the mold? Is that a different kind of microorganism?

Instructor: What do you think? Compare the ring with the color and texture of the nutrient agar in the petri dish I just passed out. How do the two compare?

Student D: There is nothing growing in the clear zone -- it is the same as the nutrient agar in the petri dish.

Instructor: That's correct. There is nothing growing immediately around the fungi. Why is the zone there? Is it coincidental that it is on the plate or is there an explanation?

Student D: Maybe something caused it. Perhaps the bacteria reacted with the nutrient agar.

Student A: That's not right. If this were true there would be a lot more clear zones scattered over the surface of the plate.

Instructor: O. K. I have an idea -- let's take into consideration all of the observations that we've listed on the board and see if we can come up with some explanations to account for or explain them. I'll now list all such explanations or hypotheses on the board.

Student C: Maybe the bacteria caused the zone.

Student E: Maybe the fungi caused the zone.

Student F: Maybe the agar caused the zone.

(The instructor lists several of the hypotheses on the board. Most students eagerly offer an explanation of some kind. One gets the full gamut of guesses.)

Instructor: Let's now see if we can examine the hypotheses and eliminate some by simple reasoning or by some simple test or experiment.

(Some of the weak hypotheses were thus eliminated; this left the more tenable ones: 1.--the fungi caused the zone and 2.--the bacteria caused the zone.)

Instructor: Which of these two hypotheses seems to be more plausible? What kind of test could we perform to determine whether the fungi or the bacteria caused the zone?

Student G: Take some of the fungi and put it on a plate with some of the same kind of bacteria growing on it. If the rings continue to occur around the mold, then we know that the mold is causing it.

Instructor: Good. This is one test that could be done. Of course we would probably want to do others too -- just to be sure. Let's work with hypothesis # 2 (fungi caused zone) and see if we can refine it. Can somebody refine this hypothesis?

Student H: Does something from the fungus cause the zone?

Instructor: What do you mean by something?

Student H: A substance or something like that.

Instructor: Good. Let's say that some kind of chemical was produced and caused the zone. How did it get out beyond the mold? If such a chemical does exist how could we prove it? What do we need to do at this point? We have refined our hypothesis to: The fungi produces some chemical that diffuses out into the agar and causes a clear zone. What do we now need to do?

Student I: Test to see if there is something in the agar in the clear zone. Do an experiment.

Instructor: Good. Very good.

(At this point I told the Alexander Flemming story about the discovery of penicillin. I pointed out how Flemming went through a similar procedure of making observations, formulating an hypothesis and experimenting to test his hypothesis.)

Instructor: We have just made an hypothesis and supported it with an experiment. If an hypothesis is true it can be used to predict new information. Let's consider this in the form of an "If. . . ., Then. . ." statement. If penicillin will inhibit the growth of bacteria in a culture dish, then . . . Who would like to make a prediction?

(Many students are familiar enough with penicillin to provide the correct response. Then it will inhibit bacteria growing in laboratory animals as well. When this response is made the instructor finishes the penicillin story by telling how Chain and Florey made a similar prediction from Flemming's hypothesis.)

Discussion Questions:

1. Is a theory or law the absolute truth about a part of the universe? Does the absolute truth carry with it the qualities of being absolutely closed to possible exception?

2. In the strictest sense, is there such a thing as a scientific "fact" or "truth"?

3. How has the invention of the microscope changed man's notion of the universe?

4. What impact has improved technique and communication had on scientific theories to principles?

Self Test:

1. Distinguish between technology and research.

2. What values were realized by the United States placing a man on the moon?

3. Is science really creative, or is it simply a careful and methodical way of putting facts together?

Answers:

1. Basic research is done primarily to further man's understanding of mature, and with possible practical applications of findings disregarded. Applied research is concerned with applying the results of pure science to practical uses.

2. Science does not make value judgements or word decisions. It is the users of scientific results who may place valuations on them.

3. Science allows for creativeness in that we have scientists who work in research.

VI. Writing Scientific Reports

Reference: Coolsby, 1970

A. The Organization of a Scientific Report in Biology

Historical accounts in precise grammar are hallmarks of the scientific report. In addition to these features, however, there is an organization of the report which has become accepted because it requires that the writer identify the way in which he has used the scientific method in his research. There are, in fact, several headings for the various sections, but all of the schemes now in common use help the reader to identify the steps in the scientific method used, that is, whether it was observational or quantitative.

Each paper has a title. Usually editors prefer titles to be 10 words or less, but exceptions are made. Following this is the name (or names) of the investigator and his professional address so that anyone may write to him for a copy or to ask questions not covered in the report. Technical assistants are not usually listed with the authors unless they contributed in some intellectual way to the research or to writing parts of the report. The order of the names is important when making references. These are the divisions of the report:

1. The Introduction is the first section and gives the historical precedents for doing the experiment or experiments, or the observations which stimulated the formation of the hypothesis. The introduction usually ends with the hypothesis.

2. The second section is called Materials and Methods or sometimes it is headed Experimental. It is here that all the materials, animals, plants or microbes; chemicals, solutions and equipment used are listed. Also, the details of any new or specific procedure are either given or referred to.

3. The Results section is sometimes called Observations in reports dealing primarily with descriptions of objects. This section has the data and graphs, but it is also a rule that the text of the results section should be intelligible even if the tables and graphs were missing.

4. The fourth section is headed Discussion. Here the results obtained by others in similar experiments are compared with the results obtained in the reported data and a logical explanation is attempted. It is here that the inductive and creative reasoning is most apparent.

5. The Summary and Conclusions form the fifth section. Here the most significant findings of the experiment are recounted as are the conclusions drawn from them.

6. The report closes with a list of References to other reports which have been cited in the text. The term "Bibliography" is used only where there is a complete listing of all books and papers on the topic.

There are several ways in which references to the literature are cited in the text. This is called documentation since these references are used to substantiate statements made by the author. Frequently the name of the author or authors and the year of their publication is used, i.e., (Brachet, 1961). Sometimes a number is placed in parentheses following a statement or other reference, i.e., the living cell is the fundamental unit of which all living organisms are made (1). Less frequently a superscript number is used, viz: The living cell is the fundamental unit of which all living organisms are made.[1] The first of these methods has the advantage that seeing the name of the author and date of publication will let the well-informed reader know what publication is being referred to without his having to turn to the list in the reference section to find out.

Some fairly standard ways of making the references list have developed. Where names are used they are frequently listed alphabetically but where they are numbered they may not be. Here are some typical references to journal articles:

George, W. C. and J. Nichols, 1948. A study of the blood of some Crustacea. Jour. Morph., 83:425-443.

Hisaw, F. I., J. T. Velardo and C. M. Goolsby, 1954. Interaction of estrogens on uterine growth. Jour. Clin. Endocr. and Metab., 14(10): 1134-1143.

The name of the journal is usually abbreviated. This one is the Journal of Clinical Endocrinology and Metabolism. The number 14 refers to the volume number and the (10) indicates that it is the 10th issue of the volume. The colon separates the volume from the page numbers. Some journals conserve space by omitting the title.

References to material in books is made in the following ways:

Dampier, William C. *A History of Science* New York. The Macmillan Co., 3rd ed. 1944, 574pp. Pages 32-40.

The titles of books are usually italicized in print and the direction to the typesetter is to underline such words once, therefore in typing and writing they are underscored. New York is the city of publication, The Macmillan Co. is the publisher and the year of publication was 1944.

A second kind of reference is to a chapter or article in a book which contains the work of several authors that have been compiled by the editor. In this case it is the chapter that is being cited and credit is to be given to the author or authors, but such an article could never be found in the library unless the name of the editor and title of the volume were known.

Miller, Stanley L. The origin of life *in* Johnson, W. H. and Steere, W. C.(eds.) *This Is Life* New York, Holt, Rinehart and Winston. 1962, 354pp. Pages 317-341.

Occasionally a book or treatise or handbook will be published not under the name of an author or editor but by an association such as the American Physiological Society. There are some popular elementary biology textbooks in this category, viz:

Biological Sciences Curriculum Study. Biological Science Molecules to Man. Boston, Houghton Mifflin Co., 1963. 716pp. 3-12.

The card index in libraries cross-references books by subject, author and title. Original articles in journals, however, are not indexed in the card catalogue but in special journals. These are discussed in the section on biological literature.

B. The Biological Literature

1. Introduction

It is not enough for a scientist to think up and carry out a new experiment. If he does not communicate his findings, he has not done anything beneficial for mankind, and in fact, he has not contributed to the available store of scientific knowledge until he does. The tradition of magic, sorcery and witchcraft was to keep its "findings" and "discoveries" private, secret and uncommunicated except to one or a few members of the family or guild. One of the characteristics of the scientific enterprise is that it is empirical and shared. All scientists are invited to repeat an experiment if they choose. In fact, scientists usually follow the rule from Deuteronomy, that "out of the mouth of two shall the truth be established". Consequently, most important conclusions will be confirmed by another scientist, or group of scientists, doing the experiment again. Once confirmed, a scientific conclusion is accepted.

The ethics of data reporting has a strong tradition that the investigator be as honest as his perception permits. Because of this ethic of honesty in reporting data, great faith is put in the results of an experiment, and it is not usually done over again except for the extension of ideas, confirmation or for instructional purposes. However, this faith does not include interpretations or opinions about the data. Different scientists will use different backgrounds for interpretation. Statistics are useful for providing some standards for deciding if experimental results are different. However, an author's experimental design, opinions and interpretations of data, his choice of experimental material, procedures and techniques may all be challenged, criticized or praised, but the data is seldom questioned before a repeat experiment is done. Thus, the literature is where scientific information accumulates and the literature then becomes not only the storehouse of accumulated knowledge but also a tool of research. Knowledge and use of the literature are hallmarks of scientific scholarship.

2. How the Literature in Biology and Biochemistry is Used?

The literature in Biology and Biochemistry includes treatises, monographs, textbooks, handbooks, books of tables, and the journals. Of these forms, the journals are the most important because they contain most of the original reports of the experiments. While the literature accumulates scientific information, it also affords a means for information retrieval. Each number (issue) of a journal has a table of contents listing authors and titles of papers. Many journal tissues also have subject and author indices. There is a journal that carries the table of contents in facsimile of many other journals. This journal, Current Contents, published fortnightly enables the reader to see what articles have been published in a large number of journals soon after their appearance. This is not an index, but an instrument of rapid communication.

Another device for rapid communication is the abstract. Sometimes the abstract appears in the journal just preceding the article but, whether this is so or not, most reports are abstracted in abstract journals. There are two widely used abstract journals published in the United States of importance to biologists. These are Biological Abstracts and Chemical Abstracts. The abstracts are sometimes written by an original author, by a scientist who volunteers his service, or by professional abstracting staff members. Chemical Abstracts indexes the abstracts by author, subject and formula. Biological Abstract indexes articles by author, subject, and animal or plant classification. In the subject indices, the key words are cross-indexed. In recent years Biological Abstracts has published a computerized subject index under the title B.A.S.I.C. (Biological Abstract Subjects in Context). These indices are published fortnightly and for each complete volume.

Other indices widely used are The Surgeon General's Weekly Index of Medical Literature and Indicus Medicus. Of less use is the Reader's Guide to Periodical Literature because of its limited scope.

Earlier in this unit we used as an example of a reference, one that reported data on the ability of estradiol-17 beta to cause growth of uteri in castrated rats. There are many papers written on this point, but we would like to direct your attention to the information in one dealing with the response of castrated rats to estradiol, estrone and estriol (all female sex steroid hormones) and to mixtures with estriol written by F. L. Hisaw, J. T. Velardo and C. M. Goolsby in late 1954. The abstract appears in 1955 and so the article is indexed in that year. What would we look for in the indices of Biological Abstracts and Chemical Abstracts for 1955? Entries for this article as indexed by both of these abstract journals are presented as examples of how the system works.

a. Biological Abstracts

The Author Index. In the author index for volume 29 (1955) we may look up one or more of the authors in the alphabetical listing. Under Hisaw, F. L. we note four numbers for that year. We may look up one of the other authors and see if any numbers of abstracts correspond or we may look up the four listed until we run across the one desired. It happens to be abstract 11155.

The Subject Index. If we look under Estrogens we find many subjects and sub-subjects. In the heading we are directed to (See also Hormones (animal), sex; Ovary (animal); Steroids; and also specific estrogens, e.g., Estradiol. Under Estradiol one finds the subheading uterotropic action and interaction with estrone and estriol, rat, 11155. The same reference appears under Estriol and under Estrone.

Abstract 11155 is reproduced below.

Hirvonen, L., 16434
Hirvonen, M., 18801
Hirwe, N., 10803
Hisada, S., 25612
Hisaoka, K., 24141A
Hisaw, F. L., 8444, 11148,
11155, 28707
Hitchcock, A. E., 9678
Hitchcock, C. B., 27710
Hitchcock, C. R., 15486
Hitchcock, D. I., 5279
Hitchcock, M. M., 9659

Extract from the Author Index

11155. HISAW, FREDERICK L., JOSEPH T. VELARDO, and CHARLES M. GOOLSBY. (The Biol. Labs., Harvard U., Cambridge 38, Mass.) Interaction of estrogens on uterine growth. Jour. Clin. Endocrinol. and Metab. 14(10): 1134-1143. 1954.--Relative effectiveness of estradiol-17B, estrone and estriol in the production of uterine growth was tested on castrated, adult rats. Animals 100 days old (200 g) were used 7 days after castration. The various doses of estrogens were dissolved in 0.1 ml sesame oil and injected subcutaneously daily for 3 days, with autopsy at the 72nd hour. Dosage-response curves based on increases in uterine wet weight showed estradiol to be about 10 times more effective than estrone. A maximal response of about 300 mg was obtained by a daily dosage of 1.0 µg of estradiol and by 10 µg estrone. Estriol was not only the least active of the 3 estrogens but was found incapable of stimulating maximal uterine growth in the 72-hr. period. Estriol in a dose of 0.1 µg decreased the growth-promoting action of estradiol and estrone when the hormones were given simultaneously. A maximal response to a given daily dose of estrogen was attained at about 72 hrs. and the weight of the uterus remained approximately the same when treatment was continued for 15 days. Uterine growth produced and maintained either by estradiol or by estrone or a combination of the 2 was reduced when estriol was added.--From auth. summ.

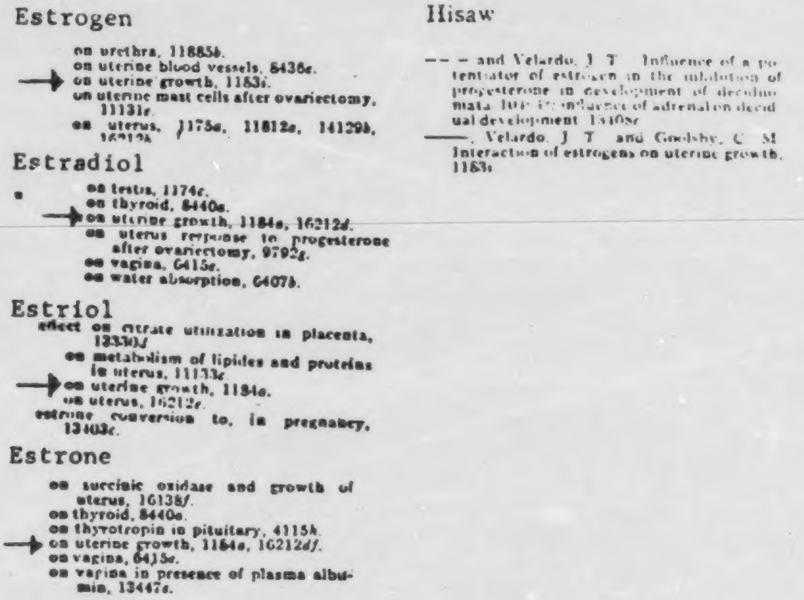
local action on vagina, metabolic inhibitors affecting, 5793
uterotropic action and interaction with estrone and estriol, rat, 11155
Estrin. (See Estrogens.)
Estriol. (See also Estrogens.)
antagonism of progesterone-induced decidual growth, factor from pregnant mare's urine as enhancing, rat, 8444
dets., in body fluids, 13170, 13171
Kober reaction for, errors, sources and correction, 5336
fluorescence spectra, 23752
identification, in amniotic fluid, 5707
in human semen, 15203
identification in and isolation from placental tissue, 8372
intravaginal instillation, optimal conditions for, 5791
metabolites, excretion and intraven. admn., 28208
urinary excretion, after estriol admn., 28209
in pregnancy after estrone administration, 5732, 8024
uterotropic action and interaction with 17β-estradiol and estrone, rat, 11155
Estrogens. (See also Hormones (animal), sex; Ovary (animal); Steroids; and also specific estrogens, e.g., Estradiol.)
action, of 2,3-bis(p-hydroxyphenyl) valeronitrile, rat, 13827
ergotoxine ethanesulphonate as enhancing, 16209
minimum effective doses, additive effects on uterus, mouse, 5313
uterotropic action, interaction with 17β-estradiol and estriol, rat, 11155

Extracts from the Subject Index

b. Chemical Abstracts

Author Index. When one looks in the index for Volume 49 one sees that F. L. Hisaw was an author for several papers during that abstracting period. In this index co-author are also listed together with the title of the abstracted article and its location, 1183i, that is, in column 1183 about .9 the way to the bottom of the page. If one looks up one of the coauthors, he is referred to the first author.

Subject Index. Again the abstract is located under Estrogens and also under the separate hormones used--Estradiol, Estrone, and Estriol.



Estrogen

on urethra, 11885b.
on uterine blood vessels, 8436e.
→ on uterine growth, 1183i.
on uterine mast cells after ovariectomy, 11131e.
on uterus, 1175a, 11812a, 14129b, 16212h.

Estradiol

on testis, 1174c.
on thyroid, 8440a.
→ on uterine growth, 1184a, 16212d.
on uterus response to progesterone after ovariectomy, 9792g.
on vagina, 6415e.
on water absorption, 6407b.

Estriol

effect on citrate utilization in placenta, 13330j
on metabolism of lipides and proteins in uterus, 11133e
→ on uterine growth, 1184a.
on uterus, 16212e.
estrone conversion to, in pregnancy, 13403c.

Estrone

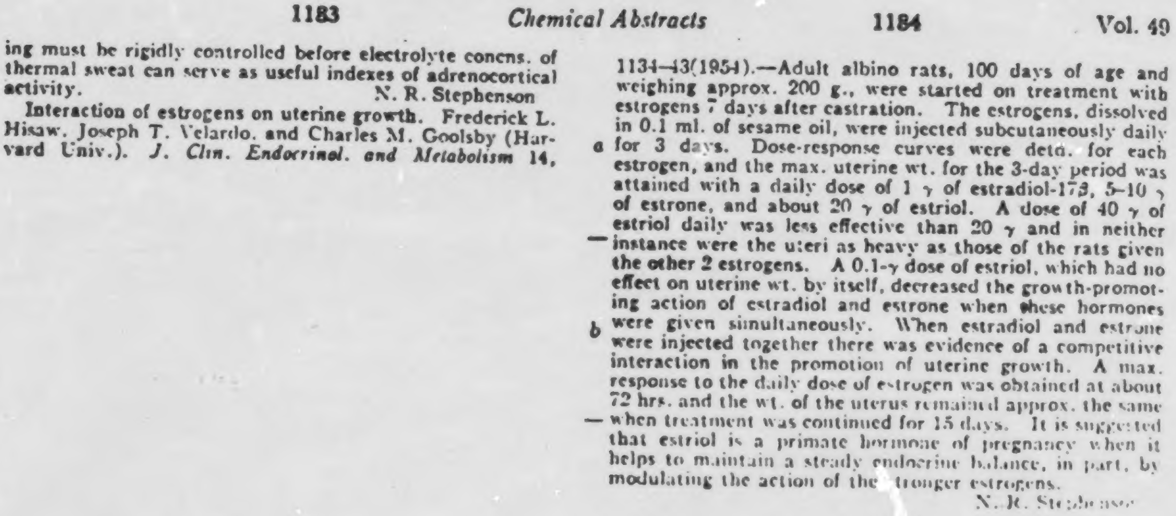
on succinic oxidase and growth of uterus, 16138f.
on thyroid, 8440a.
on thyrotropin in pituitary, 4115h.
→ on uterine growth, 1184a, 16212df.
on vagina, 6415e.
on vagina in presence of plasma albumin, 13447e.

Hisaw

— — and Velardo, J. T. Influence of a potentiator of estrogen in the inhibition of progesterone in development of deciduomata [illegible] influence of adrenal on decidual development 13408e

——, Velardo, J. T. and Goolsby, C. M. Interaction of estrogens on uterine growth. 1183i

The abstract is reproduced below.



1183 *Chemical Abstracts* 1184 Vol. 49

ing must be rigidly controlled before electrolyte concns. of thermal sweat can serve as useful indexes of adrenocortical activity. N. R. Stephenson

Interaction of estrogens on uterine growth. Frederick L. Hisaw, Joseph T. Velardo, and Charles M. Goolsby (Harvard Univ.). *J. Clin. Endocrinol. and Metabolism* 14, 1134-43(1954).—Adult albino rats, 100 days of age and weighing approx. 200 g., were started on treatment with estrogens 7 days after castration. The estrogens, dissolved in 0.1 ml. of sesame oil, were injected subcutaneously daily

a for 3 days. Dose-response curves were detd. for each estrogen, and the max. uterine wt. for the 3-day period was attained with a daily dose of 1 γ of estradiol-17β, 5-10 γ of estrone, and about 20 γ of estriol. A dose of 40 γ of estriol daily was less effective than 20 γ and in neither

— instance were the uteri as heavy as those of the rats given the other 2 estrogens. A 0.1-γ dose of estriol, which had no effect on uterine wt. by itself, decreased the growth-promoting action of estradiol and estrone when these hormones

b were given simultaneously. When estradiol and estrone were injected together there was evidence of a competitive interaction in the promotion of uterine growth. A max. response to the daily dose of estrogen was obtained at about 72 hrs. and the wt. of the uterus remained approx. the same

— when treatment was continued for 15 days. It is suggested that estriol is a primate hormone of pregnancy when it helps to maintain a steady endocrine balance, in part, by modulating the action of the stronger estrogens.

N. R. Stephenson

Introduce Exercise 1B--Scientific Reports and analyze a paper. See the Teacher's Guide to this Exercise for suggestions and further information.

ANNOTATED OUTLINE

VII. What is Science?

In this section the first objective of this unit is again emphasized. It's aim is to help the student to understand the nature of science as a vigorous interaction of the facts and ideas. The preceding sections have been used to explore what constitutes the realms of scientific study, some approaches to the acquisition of information, and ways of generalizing about natural occurrences so that principles for interpreting their meaning become apparent. Now the students should be asked to summarize what they have discussed. The teacher should not define science for the class. Instead, ask students to give their definitions (or partial definitions) from the foregoing discussions. This will help them to establish some criteria of what is science so that the following sections on areas of knowledge and belief can be discussed.

A. Folklore

Three areas of traditional beliefs for large numbers of people are listed in this section. Folklore is largely impressionistic, deceptive, and unconfirmed by experiments.

1. Magic is the art of creating the impression that man is capable of defying the natural laws. For example, the impression that matter can be created (like pulling rabbits from an empty hat), or transmuted by "magic" words (water changed to milk). It also tries to deceive the viewer into believing that work can be done without the apparent expenditure of energy as when handkerchiefs are knotted, objects float in air, etc.

Demonstration: Take a clear solution of water to which some phenolphthalien has been added before classtime. Now take some .1N NaOH, say, "Abbracadabbra!" and pour enough of it, dramatically, into the phenolphthalien until a good color is obtained. Then take some .1N HCl, say, "Abbracadabbra!" and pour in dramatically, until the solution is colorless again. (No explanation except that "it's magic".)

2. Astrology is a "confidence game" in which people are led by suggestion to believe that positions of heavenly bodies with respect to the earth governs the affairs of the natural world and of the lives of people.

3. Alchemy preceded chemistry. It sought mainly to turn cheap materials into expensive ones (for example, to turn non-corrosive lead into non-corrosive gold) or to attribute magical powers to certain materials, such as sulfur, mercury and others.) Sometimes the magic potions did contain some useful medicinal material. Thus, alchemy led into chemistry and pharmacy.

4. Discussion Question: Is folklore science? Discuss why or why not.

B. Pseudo-Sciences (Human Behavorial Studies)

These are studies where information is organized, but where it is impossible to test the validity of the concepts experimentally because man keeps adapting his behavior to the new situations. Examples are Anthropology, Economics, Social Science, Political Science and the like.

Discussion Question: Are the pseudo-scientists the victims of the prejudice of the natural scientists? Why or why not?

C. The Natural or Pure Sciences

Approach:

To show the relationship between the natural sciences and their contact with other areas of study and belief, construct the following diagram on the chalk board (or use the overhead projector). Draw the circles and add the grouping titles "Descriptive Studies", "Folklore", and "Experimental Basis (Science)", "Pure Sciences" and "Applied Sciences". Have the students correctly name the subjects (introduced in previous discussion) which belong in the various categories. It would be good to have the completed diagram reproduced and distributed after discussion so that any mis-impressions arising in the discussion can be corrected.

The diagram is on the following page. Sciences included here are:

1. Physical Sciences: Chemistry, Physics
2. Biological (Life) Sciences:
3. Interdisciplinary Studies: Biochemistry, Biophysics, Physical Chemistry
4. Applied Sciences
    a. Applied Physics: engineering and other technologies
    b. Applied Biology: agriculture, medical sciences

D. Limitations of Science

1. Science does not deal with the supernatural (See Section I. B. 5--Extra-material Universe.)

2. While scientists, as members of society, have a duty to society to take stands on the benefits and evils that beset it, science itself does not deal with the customs of the people (morals) nor theology (goodness or badness) with regard to the information it generates. For example, experiments may reveal safe, effective means of contraception but the use of contraceptives and the practice of contraception depend upon the place which information about contraception occupies in the value systems of the individual and his society. Most scientists are concerned about knowledge being used for the good of mankind instead of for his exploitation, injury or destruction. However, some do engage in "war research" developing better bombs, more poisonous gases and microbial toxins; more efficient guns and faster planes. Sometimes there is a technical by-product that is useful for peaceful purposes.

Discussion Question: What is the role of the scientist in helping society to arrive at decisions about the use of scientific information? Does science itself determine this?

E. What is the Relationship of Biology to other fields of knowledge?

Teacher References: Conant (1951a), Conant (1951b), Conant (1952)

The method of accumulating biological knowledge makes use of other areas of knowledge. Once the information is discerned, it must be integrated with what others have found and this must then be communicated to the intellectual, non-intellectual and scientific worlds.

1. Relationship of Biology to other Fields or Science and Logic.

There are other fields of science which do not really need biology for their understanding, but modern biology cannot be effectively studied without some knowledge of other sciences. A certain few exercises of a non-biological nature are always included in introductory biology courses for this reason. These include such physics exercises as those dealing with weighing and measuring, and the diffraction of light in microscopes and spectrophotometers. Some elementary mathematics is needed for determining areas and volumes, algebraic relationships (mainly ratios) and statistics for normal distribution (standard deviation and standard error) and for goodness of fit (Chi-squared). Basic elementary chemistry is needed to comprehend some reactions that occur in the study of metabolism.

The main studies of biology also involves geology, weather and climate, knowledge of folklore and mythology used for the common names of animals and **plant species**, and skill in drawing of photography. Besides these, the scientists main tools are the hand, the eye and the brain. Science is not just "ditch-digging" and coming up with a "discovery"--it is intellectual and creative.

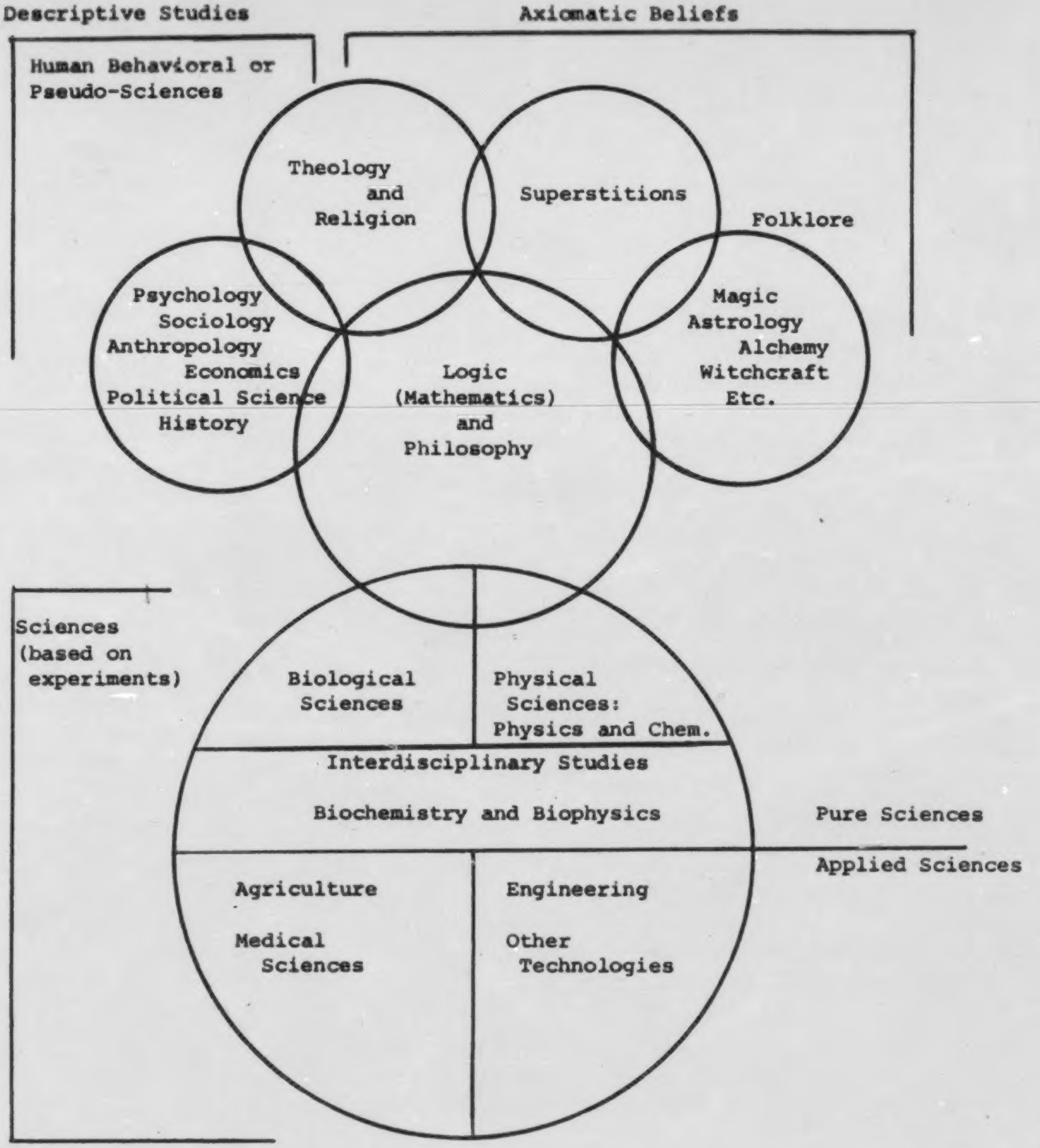
2. Relationship of Biology to Fields of Non-Science

The scientific paper (report) exposes the interdisciplinary involvement of biology and other sciences. The Introduction and Discussion sections not only require precise grammar in order to express precise ideas, but also includes the history, philosophy and logic of the investigation, The Results section, reporting quantitative data, frequently uses statistics, and higher mathematics where rates (kinetics) are considered. The whole documentation process requires familiarity with the scientific literature and library science. Many papers are read each year to local and national scientific meetings and in classrooms, and this means that the arts of good speech, graphic presentations, and even some drama become part of the good scientists equipment. The psychology of getting along with people and the salemanship that goes along with getting research grants is also important in many places, in addition to budget and personnel management ability.

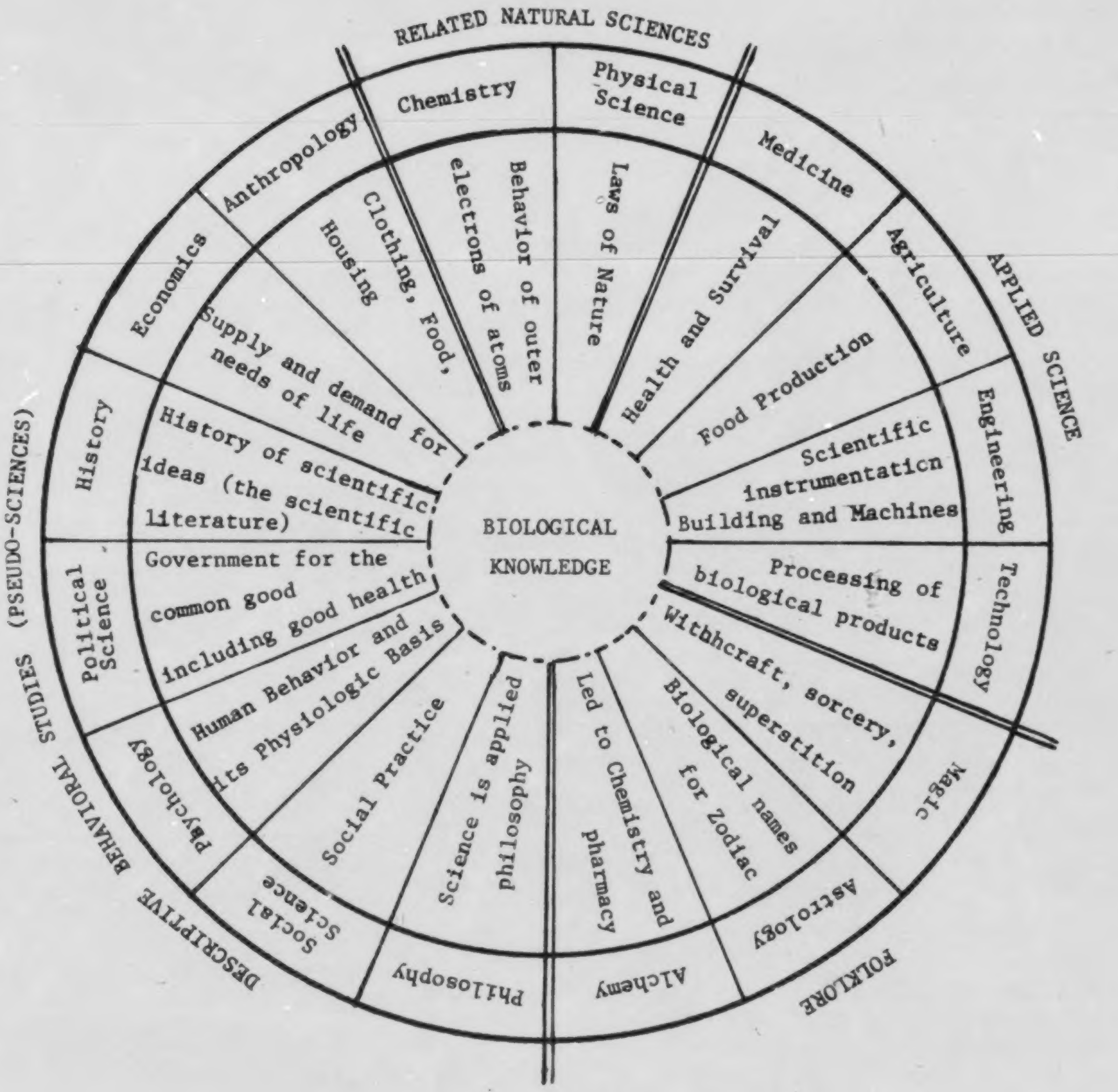
Reproduce the chart Interdisciplinary Nature of Biology on the following page for distribution at this time.

F. Why Study Science?

Teacher Reference: Sund and Trowbridge (1967) p. 19 ff.


Descriptive Studies
Axiomatic Beliefs
Human Behavioral or Pseudo-Sciences
Theology and Religion
Superstitions
Folklore
Psychology
Sociology
Anthropology
Economics
Political Science
History
Logic (Mathematics) and Philosophy
Magic
Astrology
Alchemy
Witchcraft
Etc.
Sciences (based on experiments)
Biological Sciences
Physical Sciences: Physics and Chem.
Interdisciplinary Studies
Biochemistry and Biophysics
Pure Sciences
Applied Sciences
Agriculture
Medical Sciences
Engineering
Other Technologies

The Interdisciplinary Nature of Biology
Suggested by Versia L. Lacy


RELATED NATURAL SCIENCES
Chemistry
Physical Science
Medicine
Agriculture
APPLIED SCIENCE
Engineering
Technology
Magic
FOLKLORE
Astrology
Alchemy
Philosophy
Social Science
Psychology
DESCRIPTIVE BEHAVIORAL STUDIES (PSEUDO-SCIENCES)
Political Science
History
Economics
Anthropology
Behavior of outer electrons of atoms
Laws of Nature
Health and Survival
Food Production
Scientific instrumentation
Building and Machines
Processing of biological products
Withhcraft, sorcery, superstition
Biological names for Zodiac
Led to Chemistry and pharmacy
Science is applied philosophy
Social Practice
Human Behavior and its Physiologic Basis
Government for the common good including good health
History of scientific ideas (the scientific literature)
Supply and demand for needs of life
Clothing, Food, Housing
BIOLOGICAL KNOWLEDGE

Approach:

Have students assemble information on the contributions of the following men of science, namely Dr. Charles Drew, Dr. Perry Julian and Dr. George Washington Carver. When reports have established the contributions of the scientists the teacher may ask several questions such as, "What is pure science"? "How does it differ from applied science"? "Is technology the manipulative arm of pure science"? Through discussing these questions and others, students should be able to see that applied science has its base in the work of men in the pure sciences. The students may also realize, that a doctor treating his patient, a person chopping or thinning corn, and an animal or plant bleeder, all use knowledge that they ascertained from research of pure scientists.

Discussion Questions:

1. To what extent do you agree that humanity can be divided into groups of advantage-seekers and truth seekers?

2. What is the difference in science and technology?

3. Distinguish between basic and applied research. Why is it important for both kinds of research to be supported?

4. Why is it necessary for farmers to chop cotton or thin corn?

5. How would you explain that technology is the operating arms of science?

6. What name is given to that portion of humanity that says science is simply usuable knowledge about the universe?

7. Can a so-called native tribesman in the remote jungles of Africa be a specialist?

8. The astrologer who believes in magic holds to the theory that the sun and the planets influence events on earth. Is this an unscientific theory?

9. What is applied science?

10. What is pure science?

11. How has technology influenced the life of man?

12. According to the Apocalypse, four horsemen ride over and terrify humanity. What are they? Why is biology said to be man's most effective weapon against the horsemen?

13. Why is it necessary for man to become a specialist on one aspect of the universe.

14. What are the historical and modern relations of science and religion?

15. Natural Science deals with the composition, properties and behavior of matter in the universe. If biology is regarded as belonging to this category, what other sciences belong to this group, and how do they differ from biology?

16. Are wars necessarily evil?

17. Is it important for the world to practice birth control? If so, why?

18. Is social science a natural science?

19. Is the scientific method used in the behavioral sciences?

20. List some of the positive effects of wars, floods and famine.

Self Test:

1. What is the work of a physicist?
2. Chemistry is the study of_________________.
3. Why would the study of the universe be compartmentalized?
4. What is a natural science? Give some examples.
5. Is biology a natural science? If so, why?
6. The science that treats the composition of matter is known as _____.
7. The science that deals with the behavior of matter is called ___________.
8. Why do some people think there are two major subdivisions of biology, and others think there are three major subdivisions?
9. Distinquish between vertical and horizontal organizations of the disciplines of biology. Why were these names chosen?

Answers:

1. Is to study the properties, changes and interaction of matter and energy.
2. Is a science that treats the composition of matter.
3. Because of the vastness of the universe, and man's diversed interest in the parts.
4. Systematized knowledge of nature and the physical world. Zoology, botany, chemistry, physics, etc.
5. Yes, because it a study of nature.
6. Chemistry
7. Physics
8. Historical knowledge about things was developed independently by students of plant and students of animals. However, the most important advances in biology have been by workers to bridge the gap between the divisions (molecular biology).
9. Vertical method has taxonomic base and horizontal has an operational and functional base.

REVIEW QUESTIONS

1. What is science? Give several examples.
2. Is science the product of man's curiosity? If so, explain why?
3. One author said the real reason for studying biology is the old admonition "know thyself". How would you evaluate such a statement?
4. To what extent is technology dependent upon pure research?
5. What is applied science? List some examples.
6. What is meant by "pure science"? List some examples of pure science.
7. Distinguish between an hypothesis, theory, law and principle.
8. Is a theory, law, and principle the absolute truth.
9. How may a sample from the moon's surface change the theories of man?
10. Describe the steps in the scientific method.

Classroom account by Robert J. Anthony, Jackson State College.

I am convinced that students are tuned in when they can clearly discern the whys of studying Biology or a particular unit of material. I endeavored to select as many thought provoking questions and activities as possible to capture and maintain students' interest, stimulate lively discussion, and create an understanding of:

1. The kinds of problems science attack.
2. The different kinds of Science.
3. How scientists go about solving problems and other important topics.

The unit on the Nature of Science was used to enable the students to give their definitions of science. Some of the students responses were:

1. Science is a group of facts.
2. Science is a way of thinking.
3. Science is the using of the scientific method.
4. Science is a way of solving problems.

After each student's response the students and I were very critical. The first response for example was that science is a group of facts. I immediately asked the students to define a fact. He stated that a fact was something that was true. Another student asked if all facts are true. For sometime the students and I debated on the definition of a fact. We finally concluded that a fact was a notion held by a group of people to be true. However, it may or may not have any scientific basis at all. Employing the same method to examine each of the student responses we concluded that science is a systematic body of tested knowledge resulting from a set of scientific procedures.

Before we actually finalized the discussion however, we had discussed the various kinds of sciences and introduced the scientific method. The discussion of the scientific method was really reinforced in laboratory with the black box activity (Laboratory Activities for Biology - Ex. 1)

I was able to "turn the students on" when we discussed the kinds of problems that science attacks. Students were asked what kind of problem does science attack? Some of the students answered that science tries to account for the universe and matter. From this discussion we talked about the structure, composition, and the age of the universe. One of the students thought observation stated that the whole universe is composed of matter. Using this statement as a core for discussion I presented the class with three closed test tubes one of sand, one of water and one filled with air. I provoked discussion by asking the students how are the material in the test tubes similar?

Student A: They all are in glass tubes.

Student B: They all are made up of atoms.

Student C: They all are made up of molecules.

Student D: They all are made up of matter.

From the students' responses we discussed the forms, kinds and measurability of matter.

The discussion of the measurability of matter enabled me to introduce graphs and graph interpretations to the students. I drew a graph on the board and explained the various parts of the graph such as, line, vertical and horizontal axes. The students and I walked through the actual construction of several graphs from hypothetical data. Students were given data to take home from which they were to construct graphs. The next day we discussed their constructed graphs.

Classroom Account by Robin M. Griffith, Norfolk State College

Because of the poor acoustics in the room, when we talk as a group we gather the stools up at the front of the room and made more or less of a circle. After discussing why so many incorrect guesses had been made we gathered to talk of what we had done. We talked of experimental design - hypothesis, use and importance of controls, gathering results, drawing conclusions.

One session, was spent reviewing experimental design. For homework the students had been asked to think about (a) what statement cannot be turned into an (experimentally testable) hypothesis, and (b) a testable hypothesis for which the class could devise an experiment. Among the ideas offered by individual students to the class (for which we devised experiments), were the following:

1) How can I count the fish in the ocean? This question led us into a lively debate on if we could count the fish, and the technique of sampling. It also led us to question why we'd want to count the fish and into the problem of predicting available food resources for future needs.

2) Can I take a wild animal domesticate it and have it adapt to its old environment? This brought up the issue of making generalizations from one kind of wild animal to all kinds and the importance of using a large variety of animals (and also a number of any given species) in the experiment. The question was also raised of how one defines "adapting to a new environment"?

3) Can people who eat only vegetables live as long and be as "healthy" as people who also eat meat? Here we talked of different kinds of approaches; the use of lab animals to test a hypothesis about humans (the problem of generalizing from results on lab animals to humans.) The

use of a field study . . . looking for people who fulfill our conditions, are strict vegetarians, and finding an appropriate measure of standard life span and healthiness of such a population, i.e., if we found a South American tribe of vegetarians living in the mountains, what standard do we use for normal life span or personal health?

4) Is light important for plant growth, for animal growth? How important is darkness? Here we reinforced the idea of controls, why and how they are used. Both homework questions led to interesting discussions with many students getting involved.

In my opinion, beginning the course in this way appears to have been successful. The students quickly became interested and involved. They relaxed and talked freely. They chose to skip the break we would normally take during a two hour class because they were anxious to finish the "experiment".

Although many of their explanations of what they had done or why they had guessed what they did about the contents of their boxes were sketchy, some students did work carefully and try to determine size and shape and number, did test, questions, compare, weigh, measure, and check before coming to any conclusions about their black box. The students also led one another. Because their observations were recorded on the blackboard, the less precise groups became aware of what the more careful ones had done, what kind of data they had collected, how they arrived at their conclusions. Thus, on second call many groups added more information about the contents of their box.

Classroom Account by Elizabeth D. Clark, North Carolina A & T State University

The students came talking about the recent news broadcast on hi-jacking. I started the class by saying, "There have been so many hi-jacking incidences recently. What was the latest hi-jacking feat that stirred the interest and emotions of people everywhere?" --

(S) Two jet liners were hi-jacked by the Palestine guerillas. They destroyed the planes and held 180 people as hostages. They promised to release them if the Palestine commandos held prisoners in Switzerland, West Germany and Britain were released.

I did not really want to discuss this incidence at this time. I wanted to direct the high level of interest in the hi-jacking into a discussion of hi-jacking moon rocks or dust, which are very rare on earth. Several articles had appeared in the news or Scientific Journals about these stones.

I was looking for any term that would permit a smooth transition from an attitude toward war and hostages to a scientific consideration of matter, the origin of the universe and life. So I said," Perhaps we should first discuss with one another:

(S) Hi-jacking means stealing or taking a plane.

Yes, but people were hi-jacked too. Have things other than planes been hi-jacked?

It means taking illegally and is usually associated with taking large or rare objects while in transit.

My key word was rare. So I asked, "What were the rarest objects that had been hi-jacked recently-other than the two planes mentioned? What makes the object rare? Many answers were given but it was difficult to prove that they were rare.

(S) Oh! I know. It is moon dust.

What is moon dust?-moon dust! what is it?

Rocks brought back from the moon are sometimes called moon dust.

Why are those rocks so rare and so important?

We can't go to the moon often to get moon stones so they are rare. Many stones were collected from the moon. If all of them are not studied we can not give the results of a complete study. The missing rock may have held the answer to many of our problems. (Key work problems)

(T) Very good - what are some of our problems associated with the moon? Did they appear over night? Can only our present generation be fiven credit for progress in this direction?

(S) Mrs. Clark taking first questions first - we have to try to keep the stones until we can complete our study. Many collectors or foreign enemies would pay to get those stones.

The stones were important because:

They may contain medical cure for disease.

They may hold a clue to the origin of the moon and the earth.

They may indicate whether or not life exists on the moon.

They may give ideas on the age of the moon and the earth.------

(T) In other words, we may find answers

to some of our questions by collecting data, rocks and other moon specimens. The four statements above may be reworded to express a possible conclusion which we could call our hypothesis. We could design some tests based on the hypothesis and try to find evidences of our hypothesis through experimentation using the rocks and data.

(s) For example, could we say that our hypothesis was that the moon was made of green cheese?

(T) Yes, why did man go to the moon?

(S) To see if it was really made of green cheese. (everyone laughed)

Is this hypothesis scientific or non-scientific?

(S) We may also go to see if there is a man on the moon.

Is there a reasonable idea behind this notion?

(S) If we consider the idea of a man being a picture - yes. The eyes, nose and mouth are outlines of craters or elevations on the moon.

(S) Man also went to the moon to test some of the theories based on previous studies and to explore further possible theories. So this trip was not based on emotion or just being the first to land on the moon.

(S) Since man has existed, history records man's curiosity about the moon; many men have observed and collected information about the moon.

(T) Give some means of observation.

(S) Telescopes, photographs, diagrams, direct observations (naked Eye) satellites, balloons, radiation detectors, magnetic measurement.

Are there easily observed effects of the moon on the earth?

(S) Tides, eclipse, reflected light and radio waves, effects on photoperiods and psychology and many others.

Some reasons for moon study are:

To make a comparison between the earth and the moon.

To see whether the moon has any resources that can meet the needs of man.

To see whether life exists on the moon.

To see whether the moon can provide the earth with a place to get rid of some of our wastes.

To see whether a tracking station can be set up on the moon for further exploration or exploitation.

To see whether a midway station can be maintained in space.

(T) The moon trip has opened up more avenues for research than it has settled problems. Is this generally true of scientific research? If so - why?

Yes. Because what we find may answer our questions today but as we learn more--it seems that we have simply introduced something simpler or complex that has to be worked out in the future.

(T) Very good. Look at this book (MAN'S DOMAIN, A Thematic Atlas of the World.) What does the world refer to. Will this reference have to be expanded and why?

The world refers to the earth planet. Man's domain is extending to the moon and soon - maybe to other planets.

(T) Lets summarize now, man's moon study--starting with the earliest points of importance;

The study was participated in by men of all ages, and in all fields of science and social science.

They became curious about their environment, formulated specific questions or problems, tried to assemble all accumulated information and set out to obtain more data.

They collected the data on earth, water and in space; from chemists, geologists, physiologists, astrologists, biologists, photgraphers and psychologists. They organized the data and made generalizations based on all of this information. They formed the hypothesis that man can land on the moon and return safely.

They experimented with different types of machinery and chemicals under every conceivable condition in outer space, they trained men to endure unusual situations and strain.

They determined the physiological needs of the astronauts with reference to pressure, heat, moisture, oxygen, waste stress, on organic systems and other possible factors.

Man developed technology in which they had a great deal of faith and then they experimented by sending man on a successful trip to the moon and back to earth...

Were these tests carried on only by americans?

No, by other nations also. The faith established was based on the unity of the findings of numerous tests by all scientists of all nations involved. Communication was great.

Our idea concerning the method of going to the moon is a proven theory and can be repeated - but many problems will have to be solved to reduce possible existing hazards. Much more research will have to be done in order to interpret and make use of the information obtained and to study specimens collected.

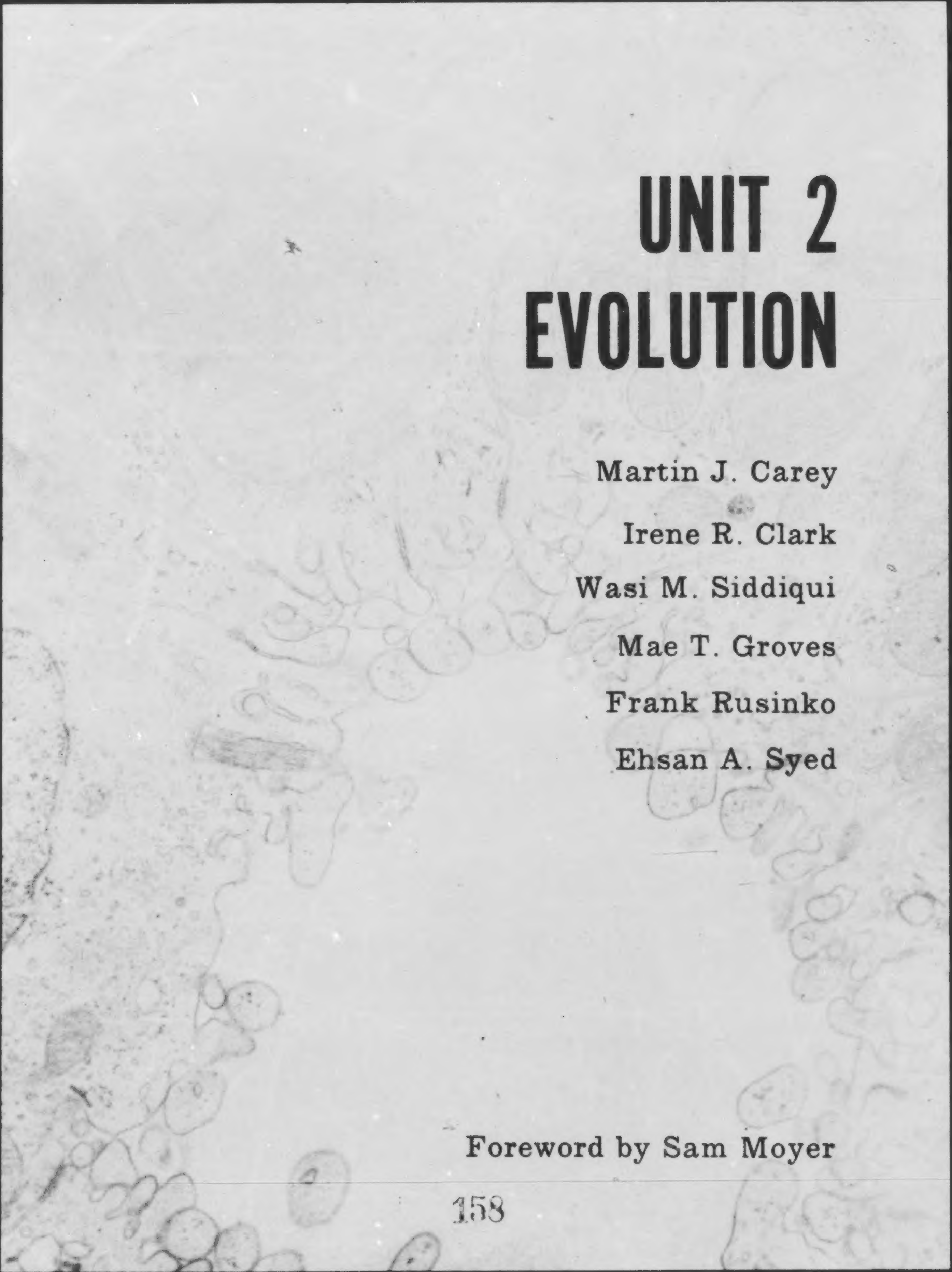
(The students had worked out the scientific method using news of interest without reading the assignment. I made the assignment on the scientific method and theories on the origin of the universe and life.)

The discussion continued on the following day.

(T) We have talked so much about the moon, earth and life--Is this our total environment or is it a part of something else?

A part of the Universe.

What is the most accepted theory of the origin of the universe? Most answers were on the origin of the earth. I asked about the sun, stars, planets, solar systems--I asked them to start with space filled with gaseous forms of matter. We discussed the primitive atmosphere. Most students could not follow the discussion because they had not studied chemistry. Monday, we will begin the study of the atom.



UNIT 2
EVOLUTION

Martin J. Carey

Irene R. Clark

Wasi M. Siddiqui

Mae T. Groves

Frank Rusinko

Ehsan A. Syed

Foreword by Sam Moyer

FOREWORD

Man has always been very curious about how life became organized as it is on Earth (and probably elsewhere). Some of this curiosity probably stems from an appreciation by man of how well organisms seem to be adapted for their existence with a touch of mystery about how they came to be that way. A practical consequence of a respect for life is the question of how life is sustained and whether the quality of organisms might be improving or deteriorating, especially as influenced by man.

Many explanations of evolution have been given since the times of earliest man. The interpretations have remained controversial. Scientific methods have provided some rather accurate answers, although many questions have not been answered so clearly.

Interest among students is naturally quite high regarding matters of evolution. It touches every aspect of biology as well as areas outside of biology, such as religion, geology and chemistry. The development of some basic evolutionary theory may be a minimal objective of this unit, but concepts of evolution can be illustrated from examples in all the other units.

There is an inherent difficulty in selecting subject matter for teaching evolution due to the broad range of the subject and a limitation in the ability of many teachers to feel competent in more than a few areas of the subject. Hence, each teacher may tend to emphasize certain segments according to his individual outlook. More important are efforts by the teachers to develop methods of motivating students, regardless of the material covered.

Therefore, the unit has been developed to provide examples of methods for presenting material in three aspects of evolution, molecular evolution, cellular evolution and human evolution in a somewhat integrated fashion. But it must be emphasized that individual teachers may wish to present other material or give different weight to the illustrated material. The main intent is to simulate the teacher with potential ideas for making any material on evolution more interesting.

Samuel E. Moyer,
Ass't Professor of Biology
Northeastern University
Boston, Massachusetts

INTRODUCTION

Evolution means an unfolding or unrolling--a gradual, orderly change from one condition to another. The planets and stars, the topography of the earth, and most species of living things today have undergone changes. The basic idea in organic evolution is that all of the various plants and animals existing at the present time have been formed from other, usually simpler, organisms by gradual modifications which have accumulated in successive generations. The theory of evolution is one of the great theories of modern science. It is an attempt to explain the historical unfolding of life on the earth as a result of the operation of natural causes, some of which reside in living organisms themselves and others which are factors in the environment.

As the student explores this unit, he will gain an insight into the important philosophical ideas and scientific discoveries leading to the evolution of present-day life forms. It is intended that the evidences and mechanisms of this process will become evident to him. But most important, however, is that the learner will see how the scientific method has been used to substantiate the theory of evolution. When these outcomes are achieved, a better understanding of the nature of science will begin to emerge - one will begin to see it as a continual interplay between growing factual knowledge and generalizations based on them.

The materials contained within this unit are primarily to serve two purposes: (1) to introduce the concept of organic change through time in conjunction with some of the experimental support for this idea and (2) to provide the fundamental information about evolutionary processes, so that the student can see its effect on, and relevance to, other biological phenomena. In this manner the fundamental components of the generalization will continuously be reinforced and firmly embedded in the mind of the student. And, once the student begins to understand some of the unifying principles in biology, such as evolution, he will then better understand the unity that exists in nature, as well as possess a deeper and more operative understanding of the principles involved. Biology is a logical and structured discipline. An understanding of evolution requires this logic and structure.

Major objectives of this unit include:

Acquaintance of the student with some ideas (theories) about how evolution occurs.

Emphasizing the Cell Theory, Recapitulation Theory and Germplasm Theory as useful guides to the continuity of life back to the "beginning".

Developing concepts of change in biology which are brought about in nature.

Learning that reproductive isolation and populational fragmentation are key conditions for genetic drift and new species formation.

Learning about the evolution of the horse as a well-studied instance of evolution and as an example of the evolution of a mammalian species.

Progress Inventory

1. What is the purpose of evolution? Is man the goal toward which all evolution has been purposely directed?

2. Does evolution imply that man evolved from apes?

3. Do you think that plants and animals today are the same that appeared when life originated?

4. What is the basis for the idea that similar structure in organisms indicate relationship? ___________

5. How have we obtained information about the remote past?

6. What is your concept of the origin of first life?

7. Was the life which originated first simpler or more complex in form than now? How were the changes that we see today brought about?

True-False

8. There is no evidence available to support the theory that the kind and relative number of species members have changed over long periods of time.

9. Man evolved directly from apes.

10. Information from embryological and genetic studies can be used to establish relationships between organisms.

11. Fossils are the only indirect evidence that can tell us of life as it may have been in the past.

12. The author of the first self-consistent theory of organic evolution was Gregor Mendel.

13. Lamarck, in his theory of the inheritance of acquired characteristics, would attribute a giraffe's long neck to stretching it in order to get food and then passing the increased length on to the offspring.

14. Mutations or genes which have suddenly changed are not inheritable.

15. Nature tends to select those species which can best adapt and reproduce to survive in the environment.

16. Darwin's concept of evolution emphasizes the inheritance of acquired characteristics.

17. Currently the most likely hypothesis for the origin of life on earth is that the first spores arrived in cosmic dust from outer space.

18. Environmental changes are indirectly responsible for species changes.

19. Spontaneous generation probably never occurred on earth.

EVOLUTION

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Darwin and Evolution: (color, 28 mins.) AIBS, McGraw-Hill.

How Living Things Change: (B & W and color 11 mins.) Coronet.

Natural Selection and Adaptation: (color, 28 mins.) AIBS. McGraw-Hill.

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In the Beginning - Esso Oil Co.

Natural Selection: (11 mins.) Encyclopedia Britannica.

Darwins World of Nature: Life Film Strip

Evolution of Man: (color - 28 mins.) AIBS, McGraw-Hill.

The Story of Prehistoric Man: (B & W, and color 11 mins.) Coronet.

Fossil Story of Story in the Rocks: Shell Oil Company

Nature of Fossils. Wards Film Strips

Fossils Key to the Past. Wards Film Strips.

TOPIC OUTLINE

A. The Idea of Change - The Evolution of the Horse

B. Theories of Evolution
  1. Lamarck
  2. Von Baer
  3. Darwin
  4. Genetic Drift

C. Theories Dealing With the Process of Evolution
  1. Von Baer's Observations
  2. The Cell Theory
  3. August Weissman

D. Evidence for Evolution
  1. Evidence from Comparative Anatomy of Animals and Plants
  2. Comparative Embryology
  3. Comparative Biochemistry
  4. Fossils
    a. Fossil Preservation
      (1) Definition
      (2) Requirements for fossilizing parts
      (3) Degrees of Preservation

E. Speciation
  1. Adaptation - Types
  2. Mechanism of Adaptation
  3. Species Defined

F. Evolutionary Divergence
  1. Some Definitions
  2. Patterns of Isolation
  3. Variation Within a Species
  4. Isolating Mechanisms
  5. Speciation and Adaptive Radiation

G. Evolution Above the Species Level
  1. Evolution of the Horse
  2. Evolution of Man

ANNOTATED OUTLINE

A. The Idea of Change - The Evolution of the Horse

Savage (1969) pp. 123-124
Simpson and Beck (1968)

Teacher References

Simpson, G. G., 1949.
Simpson, G. G., 1951.

Approach:

Make a transparency of the evolutionary diagram on page 124 (Savage, 1969) or from the original in Simpson (1951) and charts on pages 501 and 506 of Simpson and Beck (1969).

Point out the fact that the ancestor of the horse looked something like a big dog. It had 3 toes forward and 4 toes behind. It grazed in the forest. Hyracotherium was also an ancestor of the rhinoceroses.

Through the geological time periods various different animals evolved and became extinct, but some line always survived. Finally, the modern horse evolved in North and South America during the Pleistocene and radiated (migrated) to Europe by way of the Bering bridge (where the Bering Straits are now. About 10,000 years ago all horses disappeared from North and South America, probably due to some disease. They did not appear again until they were re-introduced by the Spanish conquistadors in the 16th Century. They thrived in the Americas on the great grassy plains of the pampas and of the North American midlands, their ancestral homes.

Ask students what forces do they think could have operated to bring about these kinds of changes resulting in the modern horse.

Do not accept an answer like "That is the way God made them" without some method for God having done so. Write the theories on the chalkboard. Supernatural explanations will have to be eliminated as not being able to be tested (See Unit 1).

B. Theories of Evolution

Specific References:

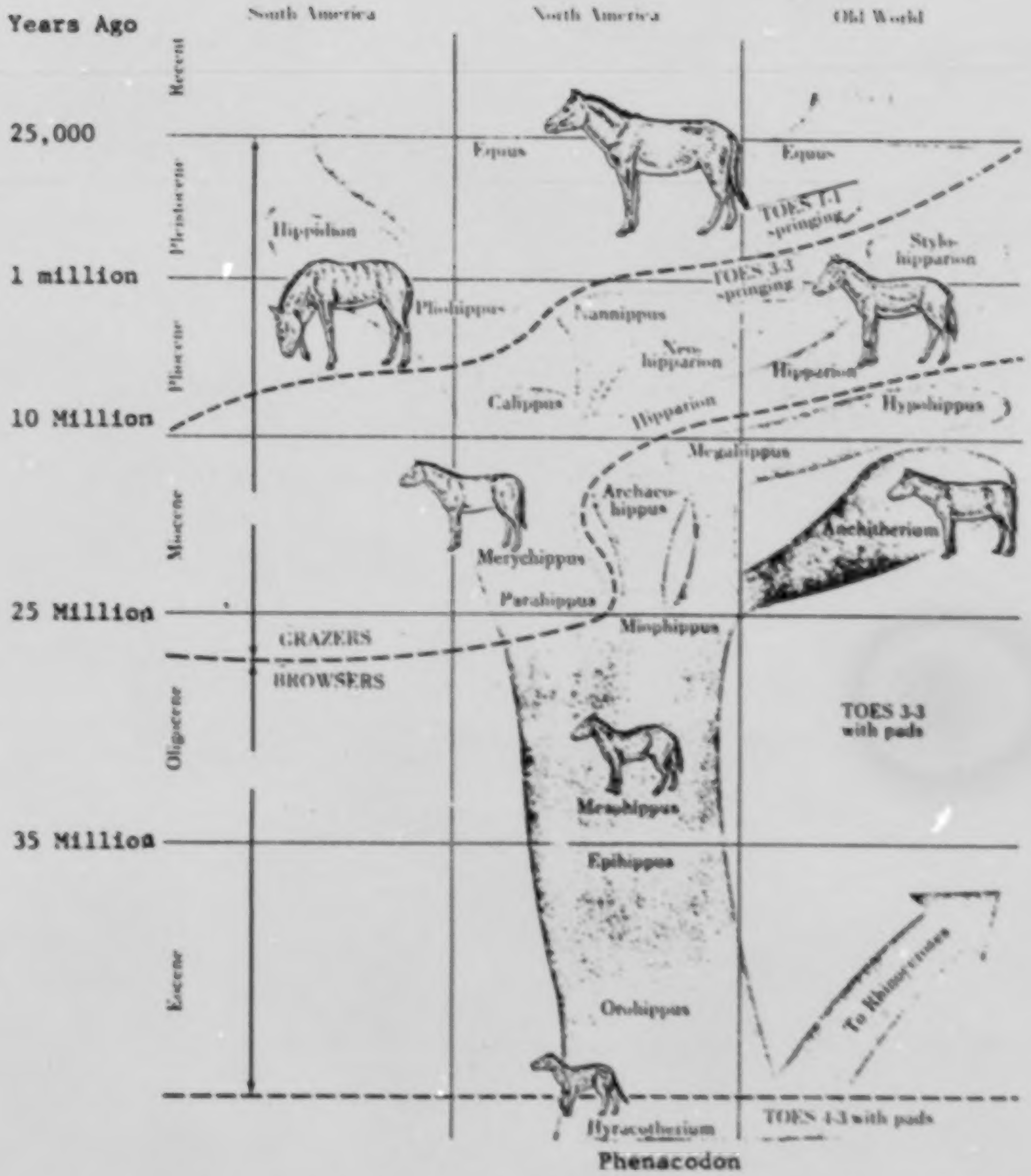
Savage (1969) pp. 13-22

Alternate References:

Simpson and Beck (1969)

1. Lamarck

In 1809 Lamarck wrote a book in which he proposed the cell theory


Years Ago
South America
North America
Old World
Recent
25,000
Pleistocene
1 million
Pliocene
10 Million
Miocene
25 Million
Oligocene
35 Million
Eocene
Equus
Equus
TOES 1-1 springing
Hippidion
Stylo-hipparion
TOES 3-3 springing
Pliohippus
Nannippus
Neo-hipparion
Hipparion
Calippus
Hipparion
Hypohippus
Megahippus
Archaeo-hippus
Anchitherium
Merychippus
Parahippus
Miohippus
GRAZERS
BROWSERS
TOES 3-3 with pads
Mesohippus
Epihippus
Orohippus
To Rhinoceroses
Hyracotherium
TOES 4-3 with pads
Phenacodon

Evolution of horses from ancestral types that browsed and had four toes on the front feet and three on the hind feet. These were padded as are dogs. Later forms grazed in the open plains and their feet were modified so that there is but a single toe on both the front and hind feet, with the legs modified for springing action in running, After G. G. Simpson (1951) that all living things were cells or cellular, and their products. He also proposed that hereditary characters could be acquired by use or lost by disuse. He proposed two conditions for the change (evolution) in organisms;

(a) new structures appear in response to the 'inner wants' of organisms.

(b) new structures appear if they are needed.

These ideas paved the way for the work of Darwin, Wallace and of Huxley. They dispelled the theory that the species are immutable.

Herbert Spencer adopted the Lamarckian view that organisms change in response to their environment.

In recent years this view was espoused by T. D. Lysenko in the Soviet Union as being consistent with Marxist ideology.

2. Von Baer (1850) observed a sequence in ontogeny and in evolution. He set forth three observations:

(a) In development general characters appear before less general ones and these before specialized ones.

(b) During development animals look similar as zygotes but depart more and more during development from the forms of others.

(c) The young stages of higher animals are not like the adults of lower forms but like the early developmental forms of lower animals.

3. Darwin proposed that evolution occurred because of natural selection. His view was that in any population variations are constantly occurring in the structure and functions of organisms. These variations occur at random, are spontaneous and not inherited. Those individuals having variations which fit them best to their environments survive best. Poorly adapted organisms die. In this way the fittest organisms are naturally selected to survive. If the environment changes, organisms with features suited to the change survive best and those with characters poorly equipping the organism for the change favor their death.

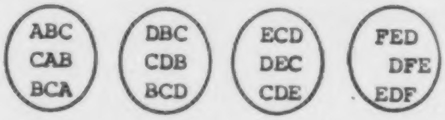
4. Speciation due to genetic drift is closely related to Darwin's natural selection. It has been shown that when a population is separated from other members of a species by some type of physical or habit barrier, some characters become more apparent whereas others become more recessive in the population, so that the isolated population begins to look differently. Factors such as natural isotope irradiation from the earth may account for some of these effects. When populations look different from other populations, it becomes a species.

Approach:

How Can You Diagram Evolution?

Diagram one of these on the chalkboard then have students try diagramming on a sheet of paper at their seats. While they are doing this, pass among them and determine which ones are different, or good, etc. After the class has finished diagramming have selected students put their diagrams on the chalkboard or make this a home assignment for presentation and discussion next time.

Darwinian
Natural
Selection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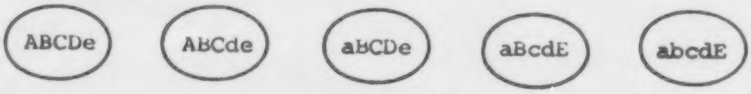
Genetic Drift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aBcdE
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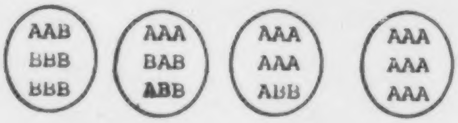
Lamarckian
Appearance or
Disappearance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SELF-TEST ON THE IDEA OF CHANGE

1. Evolutionism first developed as a/an

   a. secular and agnostic philosophy.
   b. idea of organic change.
   c. idea of religious change.
   d. idea or theory of geographic change

2. The author of the self-consistent theory of organic evolution which still holds today was:

   a. Darwin
   b. Lamarck
   c. Wallace
   d. Erasmus

3. The major fallacy in Lamarck's theory on inheritance of acquired characteristics was:

   a. the explanation was wrong.
   b. his poor style of writing.
   c. no experimentation was done.
   d. none of these.

4. Lamarck would attribute a giraffe's long neck to

   a. variations within the giraffe population.
   b. stretching it by using it to get food and then passing the increased neck on the offspring.
   c. Mutations.

5. Individuals within a population show differences called

   a. mutations
   b. traits
   c. variations

6. Darwin's theory of natural selection

   a. failed to explain the source of variation in organisms.
   b. has been replaced completely.
   c. did not account for fossils.

7. Natural selection acts upon

   a. the genetic variation within a population.
   b. the fully developed individual.
   c. the average individual.

8. Natural selection is

   a. ethically desirable.

b. morally impoverishing.
c. a fact of nature.

Answers:

4. b
5. c
6. a
7. a
8. a

C. Theories Dealing with the Process of Evolution

Von Baer's Observations that general characters appear before specific ones and that specific ones appear before specialized ones probably laid the foundation for three basic generalizations following 1850.

1. The Cell Theory

The Cell theory first proposed by Jean Lamarck in 1809 did not reach its completed state until Rudolf Virchow discovered in 1857 that mitosis was not a "thread disease" of cells but cell division giving rise to two resultant cells where before there had been but a single one. The cell theory then could be stated very much as we do today:

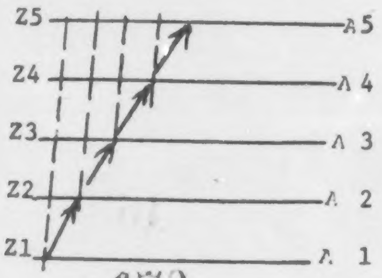
> All living things are cells or
> made of cells and their products,
> which come from pre-existing cells.

The Cell Theory has now reached the status of being the Cell Law. It says life exists only in cells and this life is passed on in cell division. Therefore, by tracing backward there are continuous lines of cells from the present, reaching back and converging on the first cell or cells, and even by implication, to the pre-cell communities of the primeval sea.

2. In the period following Von Baer (1850) there was great interest in comparative embryology. By 1866 Haeckel generalized the relationships seen in invertebrate embryos and larvae, and in the developmental stages of higher vertebrates in his Recapitulation Theory, which became known as the Biogentic Law. It's familiar statement is:

> Ontogeny recapitulates phylogeny

These words mean that the development of the individual (ontogeny) summarizes the generations of the tribes (phylogeny). This was not interpreted by Haeckel as meaning fetuses resemble the adults of lower forms, but at various stages they do resemble the developing stages of lower forms. In the diagram below Z5



From our present knowledge of genetics and of reproduction, a more up-to-date statement of the Biogenetic Law would be: Phylogeny is the result of ontogeny. That is to say, the mutations in the set of genes carried by gametes become expressed during the development of the individual. This means that evolutionary changes (phylogeny) result from the changes in gene sets which occur as an early part of ontogeny. In fact, then, all living things begin at some point as single cells.

3. August Weissman (1892) had the idea that the genetic material only recently discovered by Miescher (1881) was the connection between old and new generations of cells and organisms. He, therefore, distinguished between the plasm of the body (somatoplasm)and the plasm of the germinal cells (germplasm) He said that somatoplasm is mortal, and so is the germplasm, but if germplasm is passed on to the next generation, then all present living things can be traced back through their genetic material to the first cell or cells.

D. Evidences for Evolution

1. Evidence from Comparative Anatomy of Animals and Plants

This area of morphological study that notes the origin and development of structures in the various classification groups is based on forms. Of importance to the study of evolution are homologous, analogous and vestigial structures.

Two structures are said to be homologous if they evolved from a common ancestral structure. In addition to being similar in structure, homologous are similar in their relationships to adjacent structures and in their embryonic development. For example, a bat wing and a bird wing are similar except one has feathers, the other hair, but both feathers and hair are evolved from ectodermal scales of reptile ancestors of birds and mammals.

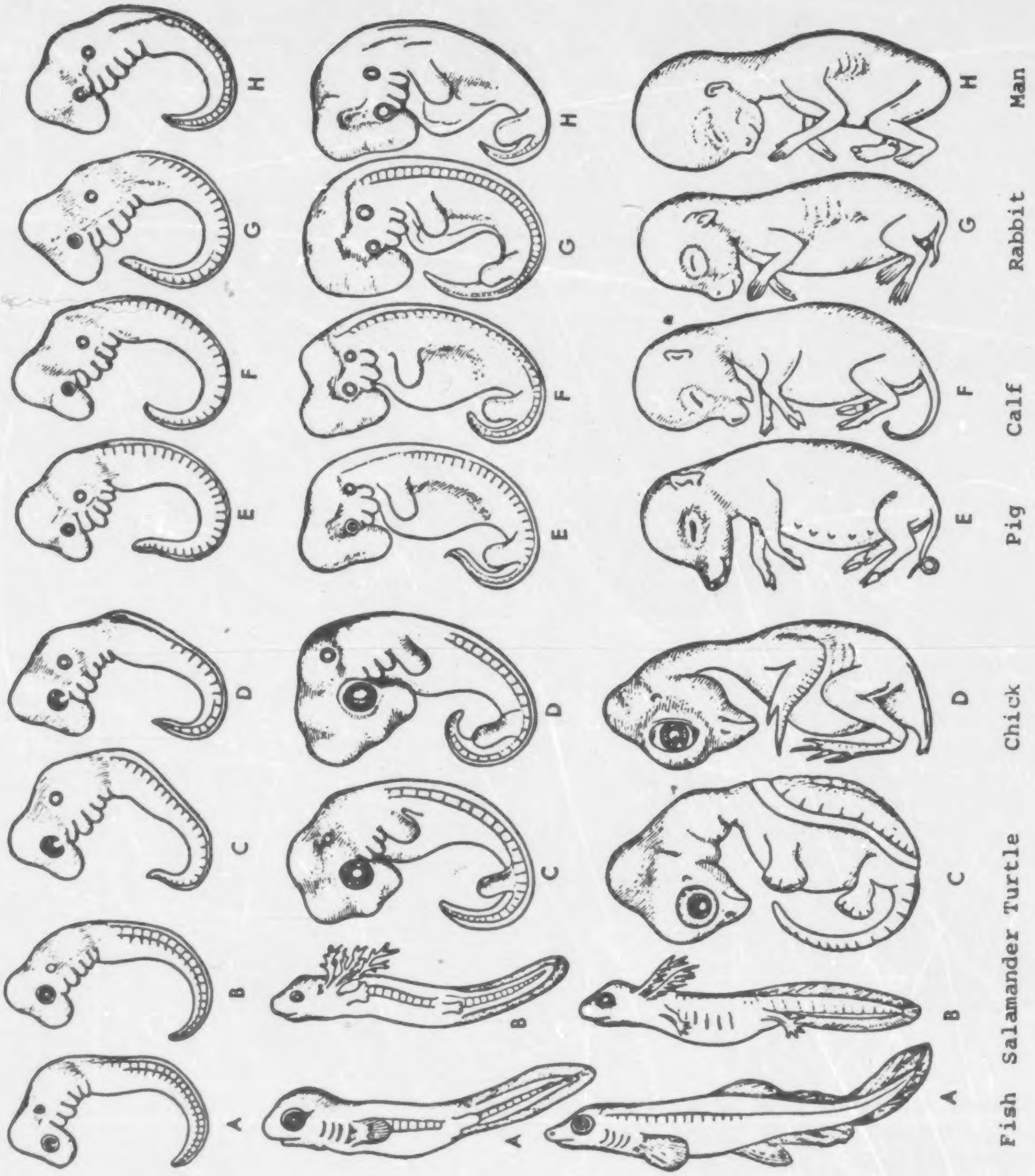
Vestigial structures are parts which are useless and degenerate, often undersize or lacking some essential structure, as compared to homologous structures in related organisms. This is also a type of anatomic evidence for evolution representing remnants of structures which were functional in some earlier organism. For example, the vermiform appendix in man is relatively short and seems not to have more than a lymphatic function, whereas in birds and plant-eaters it is long and contains cellulose-digesting bacteria whose enzymes are poured into the longer cecum.

2. Comparative Embryology

There is complete and direct evidence of evolution in the epigenesis of individual organisms. Embryological features give evidence which the morphology of adult forms no longer contain.

For example, cilia and flagella have the same construction. Flagella are single or few in number whereas cilia are smaller and numerous. Did cilia appear first and regress to flagella or was it the other way around?

Evolutionist say flagella first (see Von Baer in Sec. B). Therefore, the Flagellata are seen as the ancestors of ciliates and of higher animals. This is because it is observed that sperms are flagellate (with some exceptions) but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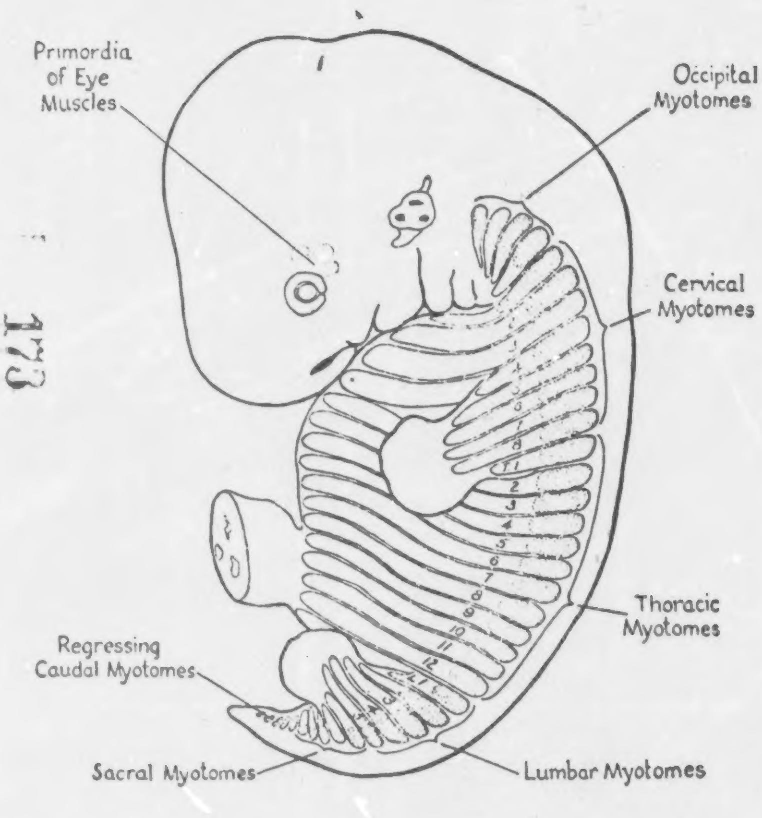
Chick
Pig
Calf
Rabbit
Man


Primordia of Eye Muscles
Occipital Myotomes
Cervical Myotomes
Thoracic Myotomes
Lumbar Myotomes
Sacral Myotomes
Regressing Caudal Myotomes
1
2
3
4
5
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7
8
9
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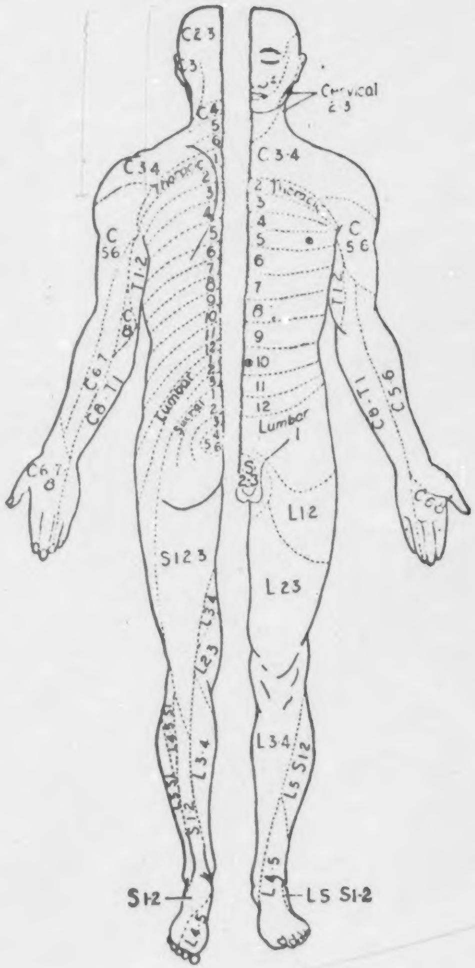
11
12

Myotomes in the human embryo


C2 3
C4
C3 4
Thoracic
Lumbar
Sacral
C 56
T1 2
C 8
C6 7
C8 T1
S12 3
L3 4
L2 3
L3 4
S1 2
L4 5
S1-2
Cervical 2 3
C 3·4
C 5 6
C5 6
C6 T1
Lumbar 1
L12
L23
L34
L5 S12
L4 5
L5 S1-2

Myotomes and innervation pattern in man.

fertilized eggs give rise to larvae (Porifera through the Echinoderms) which are ciliated.

Embryologically, the human zygote is a single-celled "Protozoan" which progresses to the two-layered condition of the coelenterates and then to the three-layered condition found in worms. The segmentation of the Annelida is less pronounced in Echinoderms but returns in the segmented embryonic muscle tissues of Vertebrates (see previous page).

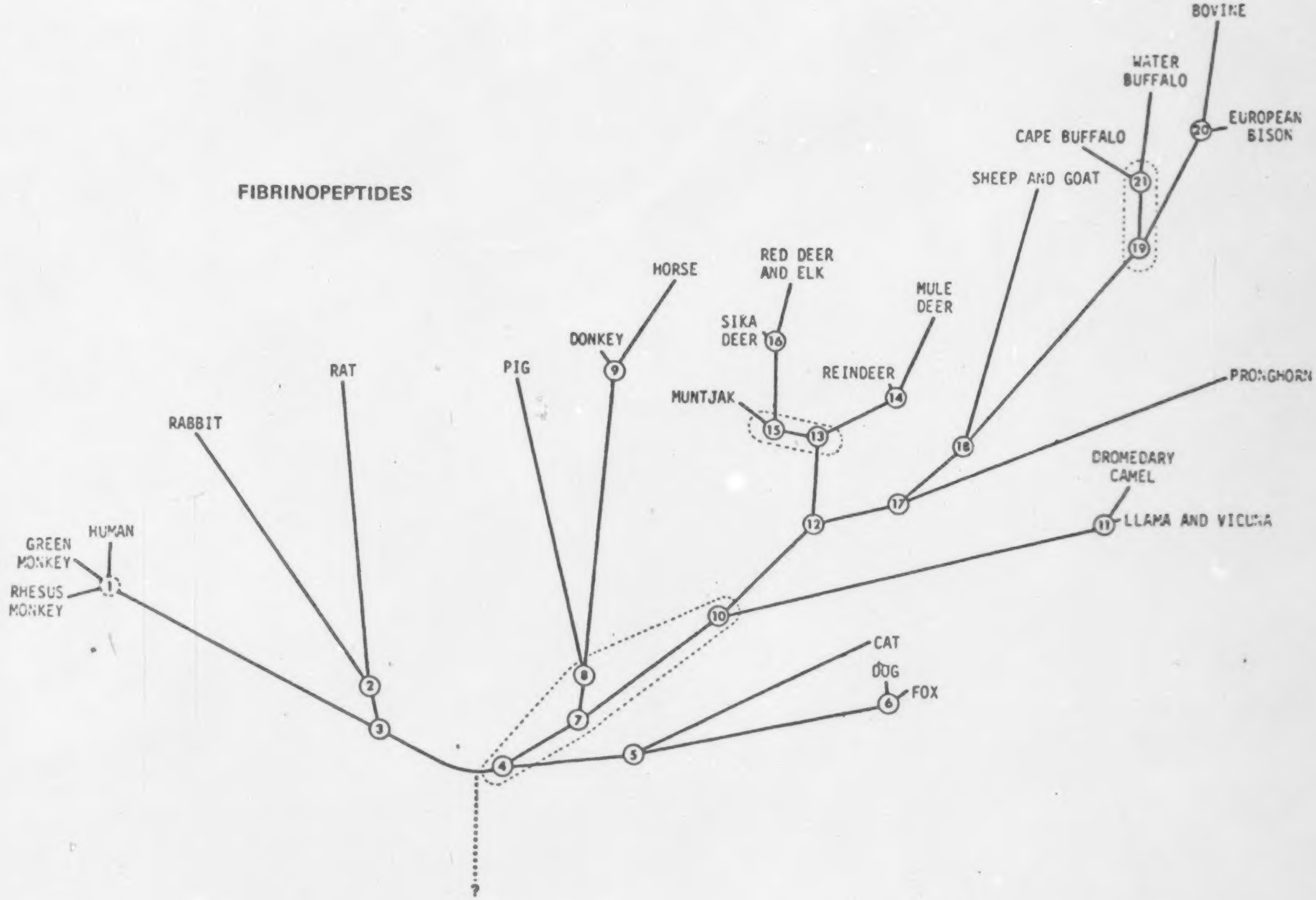
The notochord is part of the adult Prochordates. A cartilaginous skeleton of the Elasmabronchi (sharks) becomes the ossified skeleton of bony fish (Teleosts). The notochord persists in the embryology of all vertebrates, giving rise to cartilage models of vertebrae which are finally ossified as the backbone of the adult. Frogs are fish-like as larvae but metamorphose to air-breathing land animals. Higher vertebrates (including man) form the gill slits (not the gills) of fish, and live in a liquid environment until, like metamorphosed tadpoles, the mammalian fetus is ready to live in air.

3. Comparative Biochemistry

(a) Serology. Mammals have the peculiar ability to form anti-proteins (antibodies) to foreign proteins. This quality is used to form anti-sera to a very long list of proteins, especially to those in pathogenic bacteria. Since antibodies are very specific for each protein, their ability to react only with specific proteins make them very useful for quick and easy diagnosis and for the identification of the same protein in different species.

(b) Protein Analysis. In recent years automated chromatographic procedures have been developed for the analysis of the kinds and sequences of amino acids in proteins. Following is an alignment of amino acids for fibrinopeptide A for a number of vertebrates and the evolutionary relationships between the various forms of the peptide. This kind of analyses was not practical until automated chemical analysis and computers became available to do the extensive routine work involved. This kind of relationship has been worked out for dozens of proteins (including enzymes).

These peptides are part of the fibrinogen molecule, an essential for blood clotting. The enzyme, thrombin, splits off the peptide at the arginine (R) link. Any vertebrate thrombin can act on any other vertebrate fibrinogen


FIBRINOPEPTIDES
BOVINE
WATER BUFFALO
EUROPEAN BISON
CAPE BUFFALO
SHEEP AND GOAT
HORSE
RED DEER AND ELK
MULE DEER
SIKA DEER
DONKEY
PIG
RAT
REINDEER
PRONGHORN
MUNTJAK
RABBIT
DROMEDARY CAMEL
HUMAN
GREEN MONKEY
LLAMA AND VICUNA
RHESUS MONKEY
CAT
DOG
FOX
1
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?

Figure 3-12. Probable phylogenetic tree of fibrinopeptides A and B. There are many changes in these peptides, permitting inferences about the divergence of very closely related species. However, many insertions and deletions have occurred in addition to the amino acid changes. In defining relationships between more distant species, we must attempt the iterative process of determining the alignment and gaps from the homology, and the homology from the alignment. In some instances there seems to be no unique plausible solution. The most uncertain regions of the tree are surrounded by dashed lines. (The topology of the artiodactyl branch was suggested by Doolittle.)

FIBRINOPEPTIDE A

```
                                    1                   2
                  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

Human             - - - A D S G - E G D F L A E G G G V R
Green Monkey      - - - A D T G - E G D F L A E G G G V R
Rhesus Monkey     - - - A D T G - E G D F L A E G G G V R
Rat               - - - A D T G T T S E F I(D,E.G.A,G,I)P
Rabbit            - - - V D P G - E S T F I D E G A T G R
Guinea Pig        - - - T D T - - - - E F E A A G G G V R
Mink              - - - T N V K - E S E F I A E G A(A.G)R
Badger            - - - T D V K - E S E F I A E G A V.G.R
Dog               - - - T N S K - E G E F I A E G G G V R
Fox               - - - T N S K - E G E F I A E G G G V R
Cat               - - - G D V Q - E G E F I A E G G G V R
Horse             - - - - - T E - E G E F L H E G G G V R
Donkey            - - - T K T E - E G E F I S E G G G V R
Pig               - - - A E V Q D K G E F L A E G G G V R
Llama             - T D P D A D - K G E F L A E G G G V R
Vicuna            -(T.D.P.D.A.D.- K.G.E)F(L.A.E.G.G.G.V)R
Camel             - T D P D A D - E G E F(L.A.E.G.G.G.V)R
Bovine            E D G S D P P - S G D F L T E G G G V R
European Bison    E D G S D P A - S G D F L A E G G G V R
Cape Buffalo      E D G S - - - - - G E F L(A.E.G.G.G.V)R
Water Buffalo     E D G S D A V - G G E F(L.A.E.G.G.G.V)R
Sheep, Goat       A D D S D P V - G G E F L A E G G G V R
Pronghorn         A D G S D P V - G G E S(L.P,D.G.A,T,G)R
Reindeer          A D G S D P A - G G E F L A E G G G V R
Mule Deer         - - - S D P A - G G E F(L.A.E.G.G.G.V)R
Muntjak          (A.D.G.S.D.P.A.- S.G.E)F(L.T.E.G.G.G.V)R
Sika Deer         A D G(S.D.P.A.- S.S.E.F.L.A.E.G.G.G.V)R
Red Deer          A D G S D P A - S S D F L A E G G G V R
Elk              (A.D.G.S.D.P.A.- S.S.D)F(L.A.E.G.G.G.V)R

    COMMON                                      G       R

    ALLELES

                  - - - S D P A - E G E F L A E   G G V
                  A D G T N T G T S S D S I D A   A T G
                  E T D A - V K D G - T   E T D     A I
                        P K A D   K         S       V
                        - E S V   -         H
                        V   - -   T         P
                        G     Q
                              E
                              P
```

ALA	A	CYS	C	ASP	D	GLU	E
PHE	F	GLY	G	HIS	H	ILU	I
LYS	K	LEU	L	MET	M	ASN	N
TYR	O	PRO	P	GLN	Q	ARG	R
SER	S	THR	T	VAL	V	TRP	W
GLX	Z						

because the activation of fibrinogen occurs when the arginine link is broken. Upon perusal of the alignment (using one-letter abbreviations for the amino acids) it can be seen how the sequence changes with the species. The evolutionary tree is based on the number of amino acids alike in the next most-similar sequence.

4. Fossils

a. Fossil Preservation

(1) A fossil is the remains of animals or plants preserved from decay, consumption, destruction or erosion. They become part of rocks or embedded in rocks by being buried on one hard surface by mud, volcanic ash, etc.

The usual situation is that these objects were on the floor of shallow oceans (only occasionally in fresh water) and were suddenly covered with mud or sand.

More unusual ways of becoming buried include:

(a) Fall of volcanic ash followed by lava flow (Pompeii).
(b) Burial in swamps and bogs with acid waters. These are somewhat antibiotic, preventing some decay.
(c) Oil and tar pools.
(d) Preservation by freezing (Arctic ice and lakes).
(e) Entrapment of insects in resin (amber).

(2) Requirements for fossilizing parts.

Usually soft parts leave no impressions. Hard parts favor the formation of impressions and preservation of the parts. There are a few (rare) fossils older than the Cambrian epoch (600 million years ago). Then suddenly at the Cambrium representatives of all of the invertebrate phyla appear in the rocks. However, there are no vertebrates in Cambrian strata. It is concluded that animals were all soft before that time. The hard substances include:

(a) Cellulose.
(b) "Bones" and shells of calcium carbonate.
Echinoderm bones (plates) of calcite.

Aragonite, a relatively unstable salt in the shells of mollusks usually changes to calcite. In the change from aragonite to calcite microscopic structures of the organism are destroyed. Most shells before the late Teritary period have undergone this conversion.

(c) Calcium phosphate (apatite) found in vertebrate bones also occurs in Brachiopod shells.

(d) Silica is laid down in collodial form in the cells of some sponges, such as Venus' flower basket, and of

Protozoa (Radiolaria). Silica may later change to crystalline quartz with loss of details.

(e) Chitin - a glucosamine polymer. In crustacea (e.g.- lobster) the chitin is strengthened with calcium carbonate. Almost unchanged chitin is found in fossils as far back as the Ordivician.

(f) Cutin of plant cells has been found unaltered in coal and rocks.

(3) Degrees of Preservation

(a) Unaltered

(1) Frozen specimens are about the only completely preserved forms (e.g., Mammoths in Siberia with green food still in their mouths).

(2) Drownings in oil and tar pools leave bones unchanged.

(3) Cutin and chitin preserve well (see above).

(b) Replacement of Calcite or Aragonite by something else.

(1) Iron sulfide in black shale.

(2) Quartz--not attacked by acid.

(3) Permineralized - replaced by other minerals.

(4) Molds - Specimens embedded in sandstone or soapstone may be washed out by water flowing through, leaving a cavity in the shape of the specimen.

(5) Distillation - Carbon films are sometimes found on the surface. Carbon is somewhat unreactive with minerals.

(6) Tracks-clay impressions harden and are then covered with sediment.

(7) Coprolites are the fossilized excrements of animals.

Paleontologists study fossils and fossilization to determine how various factors have operated in the last 600 million years. There appears to be no difference in the environment or the requirements of life between the Cambrium period and today.

Discussion Questions - Evidences of Evolution

1. You are given representatives of two species of organisms and asked to determine whether they are closely related. What evidence would you attempt to use? (Assume that you are capable of performing necessary tests and making necessary observations).

   (Check basic anatomy and development. Are homologous structures present? Check physiology. Do processes have a marked similarity? Are same proteins found in both?)

2. Are footprints or leafprints in sedentary rock or coal considered fossils? why?
   (Yes; naturally preserved specimens of any organism are considered fossils).

3. What is the basis for the idea that similar structures in organisms indicate relationship?

   (If two species or groups had a common origin, then they should retain certain structural similarities. Generally speaking, their degree of relationship should be proportionate to their similarities in structure, but would include embryologic, physiologic, biochemical and behavioral differences.)

4. Do fossils constitute direct evidence of evolution as compared with other areas of evidence?

   (Fossils are not any more direct than other means. They only tell what kind and when the organisms actually lived in the past.)

5. Why do analogous structures not indicate kinships as do homologous ones?

   (They are superficially similar and have different embryonic origins.)

6. Why do biologists insist that the presence of gill slits in all vertebrates indicate kinship and descent from a common ancestry?

   (The biologist's interpretation fits with many other homologies found among vertebrate groups, as well as biochemical and physiological relationships.)

7. Why is it impractical to date some fossils by radioactive techniques?

   (If the decay product is not radioactive, radioactivity will be hard to measure.)

8. Why are fossils hard to find?

   (The process of fossilization, including petrification, mold and cast formation, may hide the fossil. Fossils are generally under land and water surfaces where their detection may be unlikely.)

9. What is the theory of recapitulation?

(Ontogeny recapitulates phylogeny, or that embryos, in the course of development, repeat part of the evolutionary history of embryos of their ancestors in some abbreviated form.)

SELF-TEST EVIDENCES OF EVOLUTION

1. "Evolution has occurred", is a statement that is

   a. true.
   b. false.
   c. partly true

2. The most recent method of estimating geological time is

   a. chemical analysis of rocks.
   b. decomposition of radioactive materials.
   c. study of sedimentation rates.
   d. studying well-known fossils.

3. Which of the following defines a fossil?

   a. any preserved ancient form of life or life activity.
   b. the mineralized bones of an animal or of plant parts.
   c. an impression left in plain mud by an animal or a plant.
   d. remains of a form of life no longer living, such as a dead Coelocanth.
   e. all of these.

4. What is meant by homology in a biological sense?

   a. structures which look alike and also function alike.
   b. parts of animals with similar functions but look differently.
   c. appendages which closely resemble each other but have different developments.
   d. structures which develop similarly.

5. Strong proof of close relationship between species is provided when

   a. they occupy the same geographic range.
   b. they are found in identical environments.
   c. their habits and behavior are similar.
   d. they possess a high proportion of homologous structures.

6. Which of the following areas of biology provide an abundant source of evidence to support the occurrence of evolution?

   a. Embryology and anatomy.
   b. Paleontology.
   c. Biochemistry.
   d. all of the above.

7. Comparative physiology includes which of these?

   a. Protein synthesis.
   b. Hormone production.
   c. Cellular respiration.
   d. all of the above.

8. Vertebrate gill slits illustrate the evolutionary concept that

   a. all vertebrates are basically water breathers.
   b. many vertebrates retain nonadaptive structures.
   c. fishes form a distinct group from other vertebrates.
   d. the same structure may be modified and used for different functions.

9. Biogeography is a field of study concerning

   a. distribution of living forms on the earth.
   b. location of fossil beds on the earth.
   c. site of origin of plants and animals.
   d. all of the above.

10. Comparative anatomy and development are especially important in studies of evolution for the reason that it

   a. shows how species has not changed through time.
   b. illustrates the great variation among different species.
   c. demonstrates the common ancestry of all life.
   d. provides basic information concerning relationships between living things.
   e. all of the above.

Answers:

1. a
2. b
3. e
4. d
5. d
6. d
7. d
8. d
9. a
10. e

E. Speciation

Specific References:

Savage (1969) Ch. 7

Alternate References:

Simpson, George G., 1968.

Simpson, George G., 1953

Huxley, Julian, 1966.

Grant, V., 1963.

1. Adaptation is the adjustment of an organism to its surroundings. To be more specific, adaptation is the ability of the organism to keep its intercellular environment like that in the "beginning", with changing surroundings. This places a stress on the organism. Too large a change will kill the organism. If a mutant appears that does not have to overcome stress, it may devote that energy to other activities, including reproduction, so that it soon comes to dominate the population.

Types of Adaptations are:

(a) Morphological which are the most noticeable - certain structures of an organism have become adapted for different environmental conditions or habits of the individual.

(b) Physiological adaptation (See Exercise 18) involves the functional characteristics of the organism.

(c) Behavioral adaptation involves the survival of the organism in its surroundings. Consider how an organism avoids competition in its niche or protects itself. Examples: protective coloration, poison fangs or sap in plants, stinging mechanisms, etc.

2. Mechanism of Adaptation is natural selection which operates in favor of maintained or increased adaptation to a given way of life. It is the survival of the fittest which means those individuals that have the least stresses will survive best. The individuals with the least stresses may be the group with the most offsprings and are best adapted to the conditions in which they find themselves, or are least able to meet opportunity or necessity for adaptations to other existing conditions. Note: The environment doesn't have to change in order for a mutant to be better adapted to it.

(a) Variations in the environment have been small in the last 600 million years. This implies that it is probable that two points in an organism's entire geographic range have varied little with respect to environmental conditions. Therefore, different traits have been adapted independently of drastic changes in the existing environmental conditions.

(b) Barriers are conditions that prevent genic exchange. Those may be geographical or behavioral.

3. Where "barriers" bring about genetic drift, the result is speciation.

(a) The species is a population of organisms with distinctive features. A species is a genetically similar population producing fertile offsprings. (See Simpson and Beck (1969) pp. 285 to 291.)

F. Evolutionary Divergence

Specific Reference:

Savage (1969) Chaps. 8 and 9

1. Some Definitions

a. A population is a group of genetically - similar individuals.
b. A species is the largest population of genetically - similar individuals that produce fertile offsprings.
c. A deme is a subgroup of a population and the geographical area it occupies. Related terms are:

endemic - within the deme
pandemic - throughout the deme
epidemic - upon the deme

d. Populational fragmentation refers to the isolation of smaller units into smaller demes. It is important in evolution because the genetic drift is accentuated.

2. Patterns of Isolation

a. Allopatric populations of a species are separated by physical or ecological barriers.

b. Sympatric populations of a species are physiologically separated by size, behavior, different chromosome number, etc.

3. Variation within a species

a. Random variation with respect to pattern, size, habits, etc.

b. Non-random (Ecologic) variation includes adaptations to particular kinds of local conditions such as soil type, amount of light, availability of water, etc.

c. Races or subspecies look differently but readily mate and have fertile offsprings. They usually occupy different demes and intergrades are found in areas of overlap. Where there is a gradual transition in a character from one deme to another it is referred to as a character cline.

4. Isolating Mechanisms

   a. Spatial isolation separates populations of a species. High mountains, oceans, temperature zones (tropics, arctic, deserts, etc.) do this, resulting in fragmentation and allopatric species.

   b. Physiology, behavior, populational rarity (too few to meet) are all factors operating to prevent mating. Genetic differences also operate to produce infertility or inviability, although hybrid vigor is the rule - for example: genes may not be on the same chromosome.

   c. In race formation, fragmentation and isolation are prerequisites for sufficient genetic drift to form a large, homogeneous population which differs from neighboring demes. Allopatric speciation has been and is a powerful force in evolution. Sympatric speciation is more applicable to higher plants.

   d. Reproductive Isolation.

   Radishes bloom in June. Cabbages bloom after the frost falls (about October). Pollen saved at blossoming can be used to fertilize the other species. In this way one may produce rabbages and cabbishes, but it normally doesn't happen in nature.

   Also, lions and tigers never mate in nature, but by artificial insemination of captive animals in zoos, offsprings termed ligers (lion fathers) and tigrons (tiger fathers) have been bred.

   Reproductive isolation operates to keep separate species originally allopatric.

5. Speciation and Adaptive Radiation.

Radiation refers to the movement of a species into a new geographic area. Competition or the lack of it has a marked effect on the habits of the various species. Competition leads to specialized behavior or roles, such as tree-top feeders vs. tree-bottom feeders vs. ground-feeders among birds.

G. Evolution Above the Species Level

Specific Reference:

Savage (1969) Chap. 10 and 11
Simpson (1957) 1957)
Dabzhansky, Th. (1962)

Alternate References:

Simpson and Beck (1969) pp. 500-517
Morris (1968)
Scientific American, Sept. 1960 (entire issue)

1. Evolution of the Horse.

The diagram on the following page (Simpson, 1951) shows the change in the ancestral mammal, Phenacodon, to the modern horse (Equus).

Phenacodon is found in the Eocene 75 million years ago). It was dog - or cat-like in appearance. The middle toe was longest, but had no hoof. It had a long tail.

Eohippus was 10-20 inches high. It had longer legs than its predecessors, Phenacodon and Hyracotherium. It had only 3 toes in front and 4 in the back (already reduced from five). It has a horse-like jaw in the low-crowned teeth of leaf browsers. They must have inhabited the edges of forests. (Grasseaters have high-crowned teeth to overcome the wear from silica.)

Mesohippus looks more like a small horse. Teeth are low-crowned. There are 3 toes on each foot pad, each foot pad having three small hooves. The leas are longer than for Eohippus. Habitat was river banks and the edge of forests and lowlands.

Miohippus, at the beginning of the Miocene, gave rise to three species, two of which radiated via Alaska to Asia and Europe. These were the last of the browsers.

At the beginning of the Miocene (25 million years ago) Parahippus arose in North America. It left the river banks and forest to graze in the grassy plains (Grasses had just evolved in the Miocene). It has a deeper jaw and constantly-growing, high-crowned teeth. Joints not well-fitted for sidewise movement but specialized for running.

Parahippus gave rise to several new species, notably Hipparion, which ranged into the Old World where they persisted until the early Pleistocene (1 million years ago).

Parahippus also begat Merychippus which begat Pliohippus, which was much like modern horse. The sea barrier between North and South America was removed by the raising of Central America at this time so this species ranged into South America. It was the ancestor of Equus, our modern horses.

Equus had a world wide distribution during the Pleistocene (1,000,000 to 25,000 years ago). The evolutionary direction and rate were not constant. It was slow from the Eocene to the Miocene (50 million years) then rapid in the last 25 million years.

Equus roamed North American in great herds and were here when the American Indians arrived from Asia (via Alaska) about 10,000 years ago. They disappeared about that time. Horses probably were not eaten because bison was also plentiful and persisted. The reason for their disappearance is unknown, as is also true for some other mammals that disappeared at that time. Perhaps the earth's crust shifted putting them suddenly in the cold.

When horses were re-introduced to the Americas by the Spanish conquistidors, they flourished on the vast grassy prairies of North America and on the South American pampas, for this was their evolutionary home.

2. Evolution of Man

Darwin created quite a stir in the mid-19th Century with the assertion that man evolved from the other higher premates. It must be remembered that biological knowledge of these relationships were new to people. They had thought of themselves for centuries as being created "just a little lower than the angels" and thought, somehow, that they were not related to the rest of living things. This did set off a study of the ancestry of man and a hunt for the remains of early man that continues until this day.

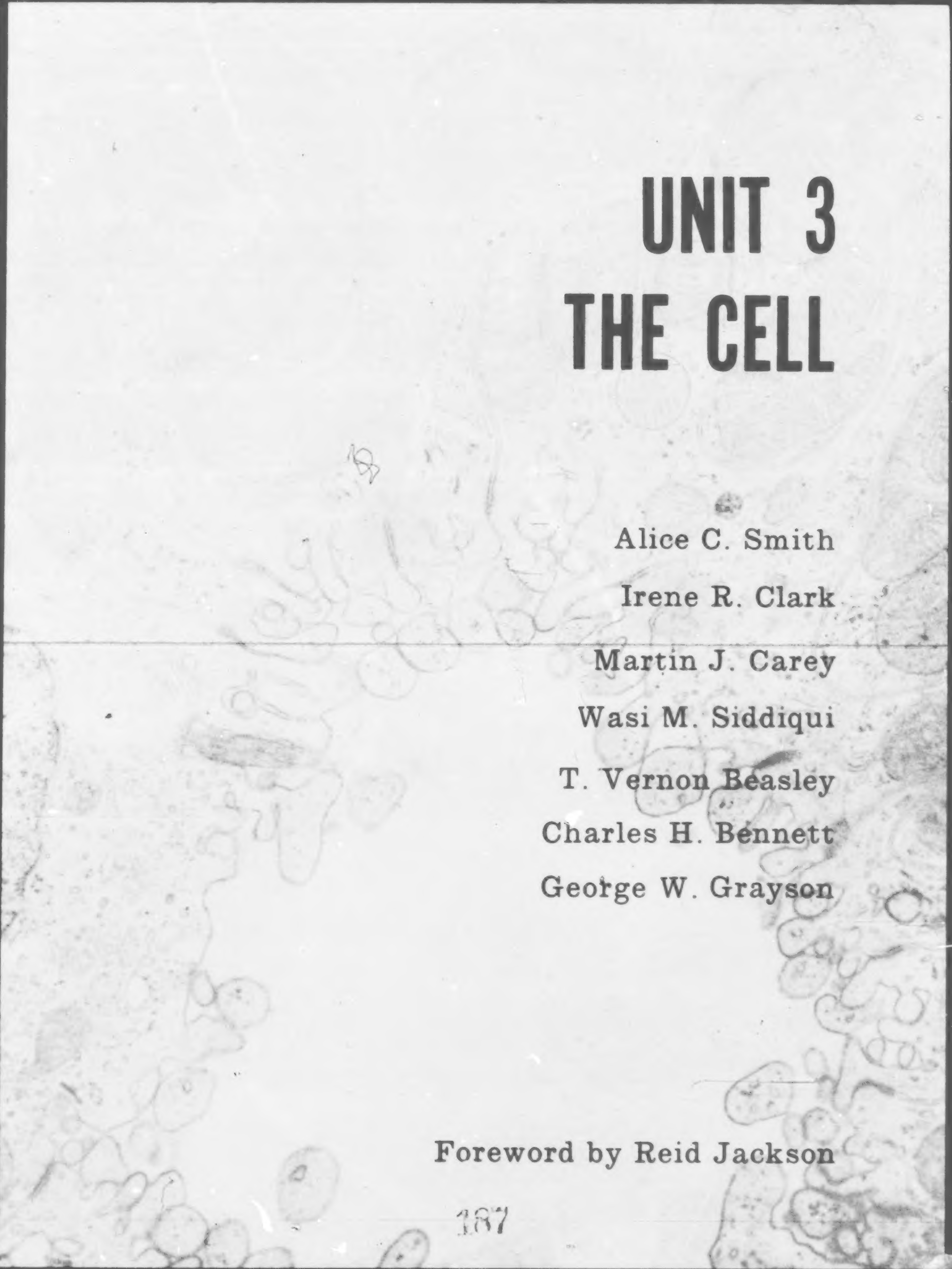
The oldest known humanoid skulls and associated stone axes and other stone tools were found by Dr. Louis S. B. Leakey, whose continuing excavations are sponsored by the National Geographic Society. Leaky has found skulls of Zinjanthropus in the Olduvai Gorge in Tanzania, East Africa. The presence of tools confirms that these beings were human, although quite primitive. The Euphrates River was supposed to flow through Eden (remember, the Book of Genesis was not written down until the time of Moses--1500 B. C.), but no skeletal parts of such age have been found in the Euphrates Valley. It appears that Africa is the ancestral home of mankind.

In the intervening period since Zinjanthropus, other types of man have lived. We name them for the places in which paleontologists have been lucky enough to find remains. These include:

Australopithecus in South Africa, and Africanus (2.5-.5 million years ago)
Homo (Pithecanthropus) in Java and Africa (600,000 to 200,000 years ago),
Sinanthropus or Peking
Homo Sapiens (1.75 million years ago to the present) - Zinjanthropus on.

Early types of Homo Sapiens (modern man) were Neanderthal and Cro-Magnon man.

Neanderthal man ranged over most of Europe, Asia and Africa. They existed before 50,000 years ago. The early form of modern man, Cro-magnon man, appeared about 50,000 years ago and ranged the same areas as Neanderthal man. About 35,000 years ago Neanderthal man disappeared somewhat suddenly. Since some present people resemble the reconstructed features of Neanderthal, it is probably that they became mixed with Cro-Magnon man in the present species of Homo sapiens. All present-day races are variants of Cro-magnon man, that is, they all belong to the species Homo sapiens.



UNIT 3

THE CELL

Alice C. Smith

Irene R. Clark

Martin J. Carey

Wasi M. Siddiqui

T. Vernon Beasley

Charles H. Bennett

George W. Grayson

Foreword by Reid Jackson

FOREWORD

Today modern biological concepts are usually advanced through literature such as the research paper, the review article, the textbook or reference book. However, these are often limited in scope by circumstances other than those dictated by the subject matter of the author. Also the cry of today's youth for relevance makes it mandatory that flexible educational programs be promoted for a total learning experience.

In all areas of science, the gulf of ignorance is widening, not because there has been a diminished capacity for learning, but because of the quantity of information that has been discovered in recent years. In biology a wealth of knowledge has been centered around the cell. Consequently, the biologist's concept of the cell during the past decade has been greatly altered by an accumulation of significant new information derived from diverse areas of inquiry. The demonstration of innumerable details within the cell as a result of studies with the electron microscope has had a major impact in this conceptual alteration. Closely associated with this morphological advance has been the assignment of biochemical and physiological properties of such structures.

The progressive development of cellular function to fine and finer levels of organization has destroyed many of our older concepts as to how various areas of cellular function are related. We now find ourselves thinking of the reulation of celluar activity in terms of the interaction between metabolic systems and the influence of macromolecular structure upon this interaction. The task of relating this information into coherent cellular concepts then, is of major importance.

The purpose of this unit, then, is to introduce in a simple way, discoveries which have enlarged the knowledge of the cellular world. The unit is designed to be simple enough so that the student or teacher with just the basic facts about modern chemistry and biology will readily comprehend. If this occurs, then there is a great chance that we can decrease the gulf of ignorance through a flexible presentation of moder facts and ideas about the cell.

Reid S. Jackson, M.S.
Graduate School of Education
Harvard University
Cambridge, Massachusetts

The Cell

Introduction

One of the statistically unlikely events in the history of the earth was the organization of some of the non-living materials in the ancient, primeval ocean into a metabolically active community of protein molecules. The energy it released from compounds in its environment was used to reproduce these proteins by activating the nucleic acids available there. This pre-cell was not just in contact with its environment, it was part of the environment. The metabolic pathways built up then are still part of the life-apparatus of all modern biological cells.

This unit has been organized to consider first the biochemical sequences of the cell which had their origins in the pre-cell community of enzymes and substrate molecules. Enough chemical symbols to follow the few formulae included are presented in Unit 1 under Matter. The teacher will note that names and abbreviations of the intermediates are given, not the formulae. The implication that the formulae are not essential to following the sequences is correct. Formulae are only codes for structure, mainly unfamiliar codes. The use of compound names is also the use of codes of more familiar form but not necessarily more familiar in meaning. To paraphrase Shakespeare, the sequence is the thing in the study of metabolism.

The second section deals with the relationship between cell activities and cell function. Part A deals with the transformation of the pre-cell into a real cell by the development of the unit membrane. This packaged the pre-cell community of molecules, creating an osmotic difference across the membrane. The ability of the living membrane to actively transport ions and molecules resulted in the creation of a battery across the membrane and therefore, the establishment of a voltage difference. This property was responsible for making the membrane irritable, that is, sensitive to changes in its environment. The membrane also made it possible for the cell to move more easily without trailing its vital molecules behind. The coacervate of proteins, nucleic acids and other molecules was thus made alive by the membrane.

In Part B of Section II the various forms and functions of cell parts are related. By this time the student should have learned what the cell must do to be alive and the role that the various parts and organelles play in fulfilling those functions should have more meaning. The organelles are considered morphologically as:

Membranous structures

Particulate structures

Fibrous and Amorphous structures

Protective coverings, and

Inclusions

This part ends with a consideration of cell division by mitosis.

The cell may be a general-purpose factory, capable of performing all the services and of manufacturing all of the products necessary to continue life. It may also be a speciality shop, doing only a single kind of job. Regardless of its nature, a cell, like a factory, must possess an organization in order to be efficient, it must contain a controlling center that somehow tells it what to do and when to do it, a source of supplies, a source of energy, and the machinery for making its product or performing its service. It is not surprising, then, that cells share many common features. If a cell becomes specialized, we might expect to find a change in organization and, possibly, the appearance of new parts but not at the sacrifice of basic features. For this reason, the biologist considers that form and function are inseparable phenomena (organized activity is associated with an organized arrangement of parts).

Part III is devoted to the historical account of cell discovery and Part IV to the conceptualization of the cell theory. Discovery alone led nowhere. The cell theory helped man understand the role of the cell in evolution, reproduction, growth, development, genetics, metabolism and regulation of the life processes, for it is only in the organization of whole cells that the living state exists.

Objectives to be sought in teaching this unit include:

Becoming familiar with the processes by which hydrogen is energized in photosynthesis and how this energy is released from hydrogen and stored during metabolism.

Becoming aware that cell foods enter and leave the energy pathways to become carbohydrates, fats and proteins interchangeably.

Understanding why cells can live only within a narrow range of conditions. To a certain degree the cell may adapt to changes in the environment.

Seeing that cell structures exist to aid in fulfilling the life functions.

Having students see the basic structural similarities and differences among the various types of cells.

Understanding the coordination of the various parts to provide maximum efficiency of the whole.

Familiarizing students with some of the important techniques and apparatuses used for cell study.

Understanding the sequence of festures in the mitotically dividing cell.

Providing insight into the unity in biology that resulted from the concept of the cell theory.

PROGRESS INVENTORY

To ascertain your comprehension of the relative size relationships at the chemical level of life, arrange the following components in descending order of relative size (largest - a, smallest - e):

1. ___ glucose molecule
2. ___ water molecule
3. ___ electron
4. ___ carbon atom
5. ___ hydrogen atom
6. ___ protein molecule

7. ___ A solution with pH 8 would be:

a. neutral
b. a very strong base
c. a very weak acid
d. a very weak base
e. a very strong acid

8. ___ Which one of the following biologists is not closely connected with the development of the cell theory?

a. Jean Lamarck
b. Charles Darwin
c. Matthias Schleiden
d. Theodor Schwann
e. Rudolf von Virchow

Match the cullular structures in the left column with their location with regard to the major features of the living cell in the right column.

9. ___ mitochondria
10. ___ nucleolus
11. ___ cell wall
12. ___ chloroplasts
13. ___ endoplasmic reticulum
14. ___ chromosomes
15. ___ centrioles
16. ___ plasma membrane

(a) at the cell surface
(b) in the cytoplasm
(c) in the cell nucleus
(d) outside of the cell membrane

17. ___ Which one of the following identifications is wrong?

a. ribosomes - site of DNA synthesis
b. chloroplasts - site of photosynthesis
c. vacuoles - storage, digestion, or excretion
d. cell cortex - internal cell support (shape)
e. chromosomes - site of DNA synthesis

18. ___ Atoms are made up of particles called

a. molecules
b. elements
c. electrons and protons
d. compounds
e. none of these

19. ___ Somatic cells (body cells) generally divide by a process known as

    a. meiosis
    b. splitting
    c. mitosis
    d. development
    e. none of these

Items 20-29 - Mark true statements, a; false ones, b.

True-False

20. ___ The most abundant type of compound found in white potato tissue is carbohydrates.

21. ___ At the electron microscope level of observation the cytoplasm of most animal cells appears to be a fairly homogenous, simple and noncompartmentalized colloidal mixture.

22. ___ Many proteins function as enzymes, i.e., they facilitate chemical reactions.

23. ___ The whole cell is the only structure known to be alive.

24. ___ Osmosis is concerned chiefly with the movement of water.

25. ___ All cells have walls of cellulose.

26. ___ Ribosomes function as centers for protein synthesis in the cell.

27. ___ Sol-gel transformations typically occur in colloids.

28. ___ "All cells come from pre-existing cells," as stated by Virchow, is now an important part of the cell theory.

29. ___ The cell membrane will allow the ready passage of all materials that are soluble in water.

THE CELL

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Available from Text Film Dept. McGraw-Hill Book Co., 330 West 42nd St., New York, N. Y. 10036

Mitosis. (24 min.) E.B.F.

Mitosis. (8 mm. film loop.) The Ealing Corporation

The Cell Principle and Biogenesis. (10 min.) McGraw-Hill Book Co.

TOPIC OUTLINE

I. Cell Metabolism

  A. Introduction
    1. Meaning of the word "cell"
    2. Living, dead, and non-living conditions
    3. A brief consideration of evolution to the pre-cell
      a) The primitive atmosphere
      b) The origin of organic molecules
      c) Macromolecules
      d) Enzymes and enzyme systems

  B. Anaerobic Glucose Metabolism
    1. Model railroad approach
      a) Glucose buys a ticket for a ride
      b) The UDP-Glucose roundhouse, multiple sugars and ribose
      c) Non-oxidative pathway to ribose
      d) The Pyruvate roundhouse and its products

  C. Aerobic Metabolism
    1. The Krebs Cycle of reactions
    2. The respiratory chain

  D. Photosynthetic Reactions
    1. The light reactions
    2. Carbon dioxide fixation or the dark reactions

  E. Fat Synthesis

  F. Protein Synthesis
    1. Protein synthesis
    2. Fibrous proteins as polymers of building block proteins
      a) Fibrinogen to fibrin
      b) Tropocollagen to collagen
      c) Tropomyosin to myosin; actin and muscle fiber structure
      d) Other fibrous proteins

II. Cell Activities Related to Cell Functions

  A. Formation of the Cell
    1. The Pre-cell Transformed to a Real Cell
    2. The Structure of the Membrane
    3. Permeability
      a) Four Old Theories of Cell Membrane Permeability
      b) Diffusion
      c) Active transport and transmembrane potentials
      d) Osmosis

B. Shapes of Cell Parts and Their Roles
    1. Protein forms and their relationship to viscosity
    2. Membranous structures
        a) Cell limit
        b) Endoplasmic reticulum
        c) The Golgi apparatus
        d) The nuclear envelope (nuclear membrane)
        e) Vacuoles
        f) Mitochondria
        g) Plastids
        h) Lysosomes
        i) Peroxisomes
        j) Other microbodies
    3. Particulate structures
        a) Nucleolus
        b) Ribosomes and polysomes
    4. Fibrous-- Amorphous and Fibrous--Fibrous Structures
        a) Centrosomes to asters
        b) Nuclear sap to spindle fibers
        c) Centrioles
            1) Structures in relation to ciliary and flagellar fibrils
            2) Role in cell division in animals and lower plants.
        d) Cell cortex and its modifications
        e) Microtubules
    5. Protective Coverings
        a) Cell wall--cellulose, lignin, protein
        b) Lorica of chitin
        c) Intercellular cement, gums and pectins
    6. Inclusions
    7. Cell Division

III. Discovery of the Cell

Hooke

Marcello Malpighi and Nehemiah Grew

Antoni van Leeuwenhoek

IV. Development of the Cell Theory

Lamarck

Schleiden and Schwann popularize the concept

Virchow deduces the origin of modern cells

ANNOTATED OUTLINE

I. Cell Metabolism

Specific References
- Kimball (1970)
- Swanson (1969)
- Goolsby (1970)

Teacher References
- Allen (1967)
- Carpenter (1967)
- McElroy (1961)
- Rhinesmith and Cioffi (1968)

Approach:

Do Exercise 7--Buffers and Indicators before doing this part of the discussion or do it concurrently.

1. Meaning of the word "cell".

Tell the class that today we are starting the discussion on the cell and ask them how many different meanings the word cell has in the English language. They will respond correctly out of their experiences. Write their answers on the board. They will include:

Jail cell, fuel cell, communist cell, monastery cell, biological cell, honeycomb cell, and dry-cell or wet-cell battery.

In general what does the word mean? (It means a relatively small box or container. The word has its root in the Greek word, Kytos -- pronounced ki-tose -- which has the root cyto--and means a box).

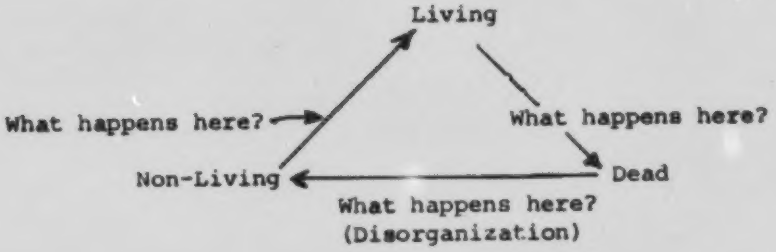
Underline "biological cell" and indicate that this is the kind of cell that we will want to study. Then ask, "Who has any idea where biological cells come from and what they do?" Write these answers on the board too. They will probably include responses like:

God made them.
They have always existed.
They just happened.
Etc.

Then suggest a closer look at some of these ideas. They may not be entirely untrue.

2. Living, dead, and non-living material.

Write this diagram on the board or prepare it ahead for use on the overhead projector:



Living material is non-living material organized in such a way as to permit the expression of the phenomena of life. What happens, then, on death? There is a slight disorganization (See Unit 8, page 14), but the material still looks mainly like living material. Digestion can break down the large molecules of protein, starch and fat found in cells. This will return the material to the non-living condition, that is not alive and not possessing the form of living material. Rocks and other chemicals (amino acids, sugars, acids) are non-living.

3. A brief consideration of how life started.

a. The Primitive Atmosphere

Let us consider a few points in the development (or organization of non-living material into living material).

Reference: Goolsby (1970) Chap. 3

Ask, "Do you believe that the earth today is the same as it was when it was formed?" Explain. Get some responses from the class. Then go on. Scientists have found that the earth today is not like the earth was in the beginning. They arrived at this conclusion by way of a fantastic scientific study. Who knows what it was? The sun and its planets were all formed out of the same galactic cloud dust, therefore, they should all have the same composition. But that is not so. What can you tell about the atmosphere on Venus? on Mars? on Jupiter? If no one knows, get some volunteers to look this up before the next class meeting.

The early atmosphere of the earth must have been much like that of the sun, but it evaporated into space because the gravity of earth was not enough to hold it here. Then as the earth cooled, a second atmosphere was exhaled from the rocks. This consisted mainly of:

H_2	hydrogen
OH_2	water (as clouds)
NH_3	ammonia
CH_4	methane (cooking gas)
CO	carbon monoxide

Other gases in smaller amounts

The same rules were in effect then as now regarding the reactions of the elements. The water vapor generated a lot of static electricity and this was one source of energy for making these gases react. Ultra violet light from the sun and isotopic radiation from the earth were two other important sources of radiation which provided energy to make these gases react. The result was the generation of many organic molecules--simple sugars, amino acids, fatty acids, and the purines and pyrimidines found in nucleotides. These organic compounds were rained down on the earth, and the oceans, thereby, increased their size ten times to occupy the present 3/4 of the earth's surface. This probably took about 1 billion years.

Examples of compounds formed are:

sugars--glyceraldehyde
amino acids--glycine, alanine, serine
fatty acids--butyric, propionic, pyruvic, succinic acids
bases--adenine, guanine, cytosine, thymine and uracil

c Macromolecules (macro--big)

It is of great importance that the amino acids began to polymerize in this sterile sea. Perhaps their linkage was catalyzed by certain crystals, or other solid-phase particles (or other polymers, such as resins). Since proteins tend to break down in water solutions unless some energy is supplied, the ability to find some source of energy was of prime importance to survival of particular strands. The ability to get the energy lay in the ability of the proteins to become shaped around other small molecules in the sea, such as glucose, glycerate, pyruvate, succinate, and others. These compounds contained energy stored there in hydrogen atoms by the lightening and irradiation. The job was to get the energy out of the hydrogens. The ability of proteins to split compounds apart is reversible, so that the products can also be put back together again. This ability in proteins is what makes them enzymes. The material acted upon by enzymes is called the substrate, and the substrates had the needed energy stored in them.

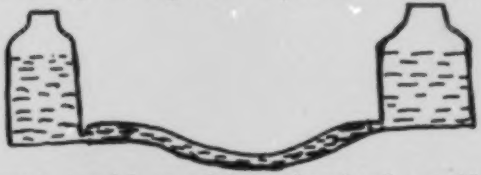
[At the next laboratory period have the class do Exercise 8--Coacervates and Emulsions, and Exercise 9--Water Content of Various Tissues and Cells. Consult the Teacher's Guide to these Exercises].

Enzymes are proteins that speed up biological reactions by lowering the amount of energy needed to make the reactions go, and without becoming part of the final products. If there is a lot of substrate and no product molecules in contact with the enzyme, the enzyme will set about splitting the substrate until the number of product molecules and the number of substrate molecules in contact with the enzyme are equal. Then it will be at equilibrium and all activity will stop. The reaction can be reversed by adding more product molecules. Under these conditions the enzyme will form more substrate molecules until equilibrium is again reached. Here is an example:

$$\underset{\text{(Substrate)}}{\text{Glucose-6-Phosphate}} \rightleftarrows \underset{\text{(Product)}}{\text{Glucose-1-Phosphate}}$$

As long as the enzyme is acting, energy can be released or used up, but if a state of chemical equilibrium is reached, the reaction is, of course, stopped, and this is the state of metabolic death!

Demonstrate this idea by using two aspirator bottles and a piece of rubber tubing, viz:



The living state must avoid reaching chemical equilibrium. It can do this by having the product removed. Three common ways of doing this are:

1. Formation of a neutral product such as water.

2. Formation of a gas that escapes the reaction, such as hydrogen, carbon dioxide, ammonia or methane.

3. The product was stored in a chemically reusable but metabolically inactive form. Because this latter was the apparently most common one, then proteins that could survive began to do so better in "communities" of molecules where the product of one reaction became the substrate for a following reaction. Not only then was there a community of enzymes and other molecules, but they constituted systems of enzymes which converted a substrate like glucose into a stored form such as starch, glycogen, cellulose, etc., or metabolized it to alcohol, lactic acid, or an amino acid like alanine.

The nucleotides were also present in the primeval sea, and had a chemical affinity for proteins then as now. There is evidence that the proteins were able to order the sequences of nucleotides by working through the reverse process that cells presently use to form proteins. That is, transfer RNA attached to the amino acids in the proteins, messenger RNA was built up on the transfer RNA, and the DNA was ordered off of the messenger RNA. The system then became reciprocal with DNA being the stable memory for the protein sequence, messenger RNA the temporary memory, and the protein sequence could be preserved PROVIDED that the protein system could provide energy from some substrate in the environment. Loss of an enzyme or of a substrate would cause part of the system to come to equilibrium, and consequently die.

Thus, the community of molecules had two characteristics of living things:

1. Metabolism for the release of energy from "foods".

2. The ability to reproduce.

However, it was not yet alive.

The first enzymes appeared when the earth still had a reducing atmosphere (all of the oxygen was combined with other elements such as silicon (quartz and sand) aluminum (clay) and in various ores (iron, copper, etc.)). The first enzyme system began with glucose. The first enzyme systems did not use oxygen and therefore, were anaerobic (without oxygen).

Let us examine the anaerobic pathways for metabolizing glucose to storage and end products.

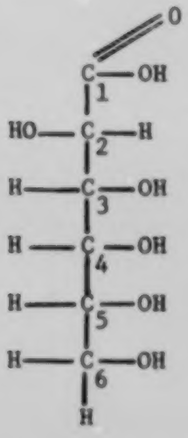
B. Anaerobic Glucose Metabolism

The metabolic schemes in this section should be reproduced and distributed to the class at this time for discussion. A transparency for overhead projection may also be prepared or the scheme may be drawn on the chalkboard.

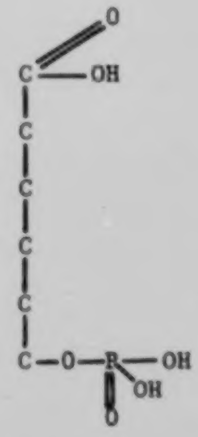
1. The Model Railroad Approach

Let us consider the metabolic pathways to be like a railroad system in which the enzymes form the rails, their substrates and products are the stations, and glucose molecules are the passengers. In order for glucose to ride, however, it must have a ticket. This ticket is a phosphate ($-PO_4$) group, and without it glucose cannot be used. In higher animals glucose must also have a passport, the protein, insulin, is needed to help add phosphate to (i.e., phosphorylate) glucose. Higher animals that lack insulin have diabetes mellitus and glucose accumulates in the blood because the muscles and connective tissues cannot get glucose into their cells wihtout the insulin passport.

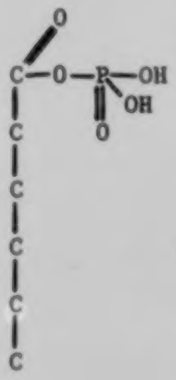
Glucose has six carbon atoms and the formula may be represented as shown below. The carbons are numbered. The phosphate goes on Carbon 6 first to form glucose-6-phosphate. This being done, glucose may ride in any direction on the railroad.



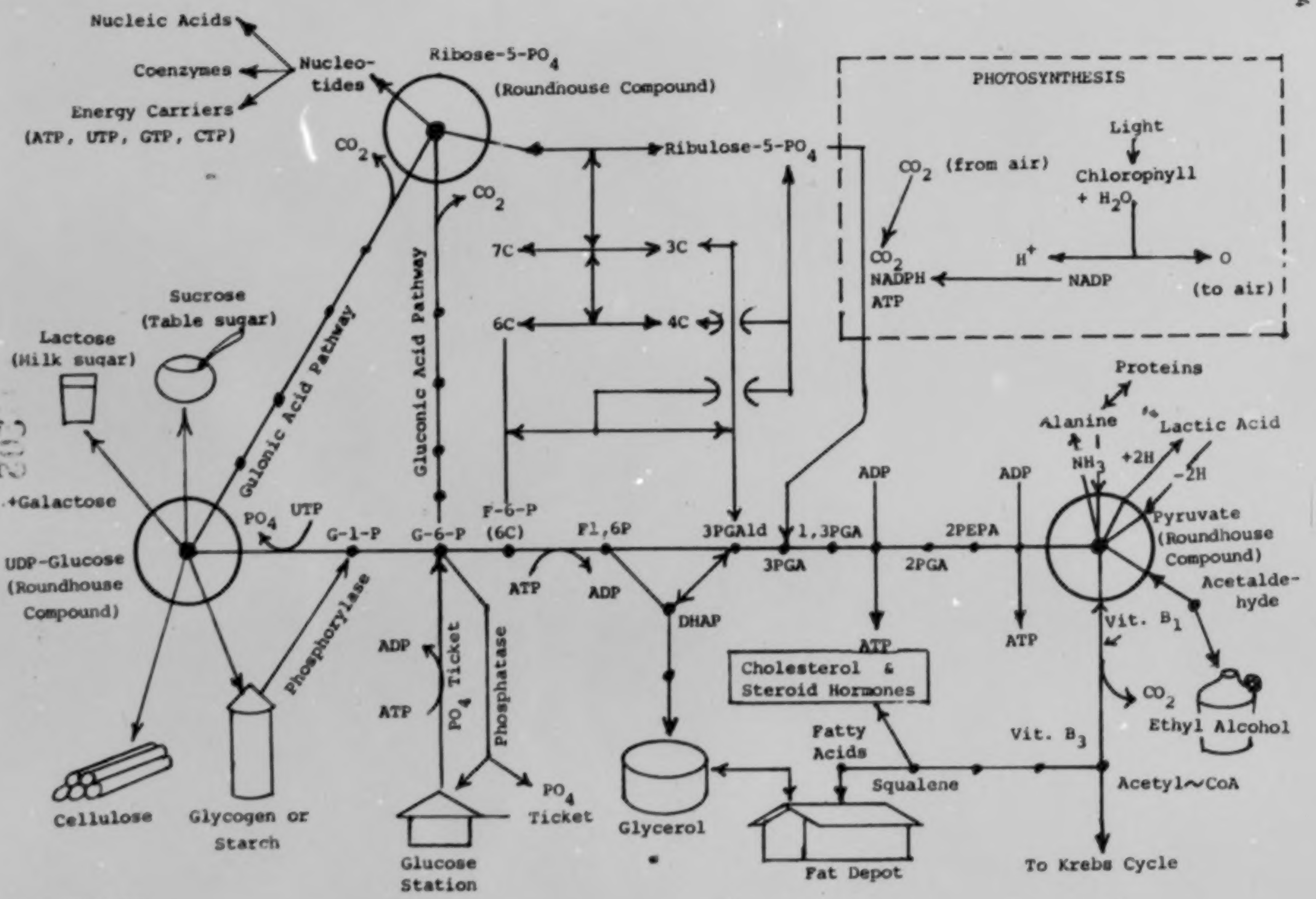
Glucose



Glucose-6-PO_4



Glucose-1-PO_4


Nucleic Acids
Coenzymes
Energy Carriers
(ATP, UTP, GTP, CTP)
Nucleo-tides
Ribose-5-PO$_4$
(Roundhouse Compound)
CO_2
CO_2
Ribulose-5-PO$_4$
PHOTOSYNTHESIS
Light
Chlorophyll
+ H_2O
CO_2 (from air)
CO_2
NADPH
ATP
H^+
NADP
O
(to air)
7C
3C
6C
4C
Sucrose
(Table sugar)
Lactose
(Milk sugar)
Gulonic Acid Pathway
Gluconic Acid Pathway
+Galactose
UDP-Glucose
(Roundhouse
Compound)
PO_4
UTP
G-1-P
G-6-P
F-6-P
(6C)
F1,6P
3PGAld
1,3PGA
3PGA
2PGA
2PEPA
ADP
ATP
ADP
ATP
ADP
ATP
ADP
ATP
DHAP
Phosphorylase
ADP
ATP
PO_4 Ticket
Phosphatase
PO_4
Ticket
Cellulose
Glycogen or
Starch
Glucose
Station
Glycerol
Cholesterol &
Steroid Hormones
Fatty
Acids
Squalene
Fat Depot
Proteins
Alanine
NH_3
Lactic Acid
+2H
-2H
Pyruvate
(Roundhouse
Compound)
Acetalde-hyde
Vit. B_1
CO_2
Ethyl Alcohol
Vit. B_3
Acetyl~CoA
To Krebs Cycle

C. M. Goolsby

The rail system consists of a mainline with a roundhouse at each end that shunts things off into various other compounds. There is also a third, very important roundhouse, so important that there are three spur lines leading to it. In addition there are a couple of spur lines to the fat depot and a connection with photosynthesis.

a. Glucose Buys a Ticket for a Ride.

Glucose reacts with ATP (adenosine triphosphate) with the help of the enzyme hexokinase (activator of 6-carbon sugars) to yield glucose-6-phosphate. This occurred in the primitive ocean. (We aren't even dealing with a cell yet, just a community of molecules.) Later, when a membrane is formed, this reaction will occur at the membrane. Glucose-6-phosphate may be reconverted to glucose and phosphate again by the enzyme phosphatase.

b. The UDP-Glucose Roundhouse.

Glucose-6-phosphate is converted to glucose-1-phosphate and this reacts with uridine triphosphate (UTP) to yield the energized form of glucose--UDP-glucose. With the appropriate enzymes, UDP-glucose will react with itself to remove the phosphate and link to another glucose molecule to form maltose and then starch, or with the proper enzyme, to form glycogen. With still a third enzyme it will polymerize to form cellulose in plants. Of importance to mammals is the old reaction in which UDP-glucose reacts with galactose to form lactose, or milk sugar. Another reaction which becomes important to plants is that UDP-glucose reacts with fructose to yield sucrose or table sugar. Sucrose is the transport form of sugar for plants just as glucose is the transport form of sugar for animals. UDP-glucose can also be oxidized by way of gulonic acid to ribose -5-phosphate. Ribose-5-phosphate is also formed from the oxidation of glucose-6-phosphate by way of the gluconic acid pathway.

c. Non-oxidative Pathway to Ribose-5-Phosphate.

The oxygen on Carbon 1 of glucose is shifted to Carbon 2 by an enzyme, forming fructose-6-phosphate (F6P). This compound "buys another phosphate ticket" by interacting with ATP to yield fructose 1, 6-diphosphate (F1,6P). F1,6P breaks in half, yielding 3-phosphoglyceraldehyde (3PGAL) and dihydroxyacetone phosphate (DHAP). These two compounds are very similar and convert to each other easily with the aid of the enzyme aldolase. Dihydroxyacetone forms glycerol (glycerine), an alcohol used in fat synthesis.

F6P and 3PGA react to form a 9 carbon intermediate which breaks down to yield erythrose (4C) and ribulose-5-phosphate (5C). The ribulose is easily converted to ribose-5-phosphate.

Ribose, and its hydrated form ribulose, each has 5 carbons, that is, 10 carbons altogether. In the non-oxidative pathway, instead of losing carbon dioxide, compounds are combined to form intermediates of 9 or 10 carbons and these split apart in various ways, viz:

> fructose-6-phosphate (6C) plus erythrose (4C) = 10 carbons -- splits to form sedoheptulose-7-phosphate plus 3PGA = 10 carbons -- which splits to form ribose-5-phosphate (5C) and ribulose-5-phosphate (5).

In this connection, photosynthesis plugs into the system. Six carbon dioxide molecules from the air, 12 activated hydrogens on NADPH, and 18 ATP react with ribulose-5-phosphate etc., yielding 12 molecules of 3PGA, two of which condense to form fructose 1, 6 diphosphate and from there it can go on to be deposited as starch by UDP-glucose.

d. The Pyruvate Roundhouse and its Products.

The 3PGA is oxidized to 3 phosphoglyceric acid (3PGA). The 3PGA is phosphorylated with phosphoric acid (not ATP) to form the unstable 1, 3 diphosphoglyceric acid (1,3PGA). This gives up one of its phosphates to ADP, forming ATP and 2 phosphoglyceric acid (2PGA). This is then converted to 2-phospho-enol-pyruvic acid (2PEPA). This also has a non-resonant (energy-rich) phosphate bond which it gives up to another ADP molecule to form ATP and pyruvic acid, the roundhouse compound. Note: Each glucose molecule (6C) yields two 3PGA (3C). Therefore 4 ATP are formed per glucose molecule. Two of these are used to phosphorylate glucose and F6P yielding 2 ATP for cell energy use.

There are several fates for pyruvate (the ion of pyruvic acid). It reacts with ammonia (NH_3) to form the amino acid alanine, which is easily converted to other amino acids (glycine, serine, phenylalanine, etc.) and therefore, is in equilibrium with proteins. It will react with 2 hydrogen atoms (2H) to form lactic acid, and lactic acid will give up 2H to oxidative enzymes to yield pyruvate again. With the loss of carbon dioxide, pyruvate goes to acetaldehyde and from there to ethyl alcohol.

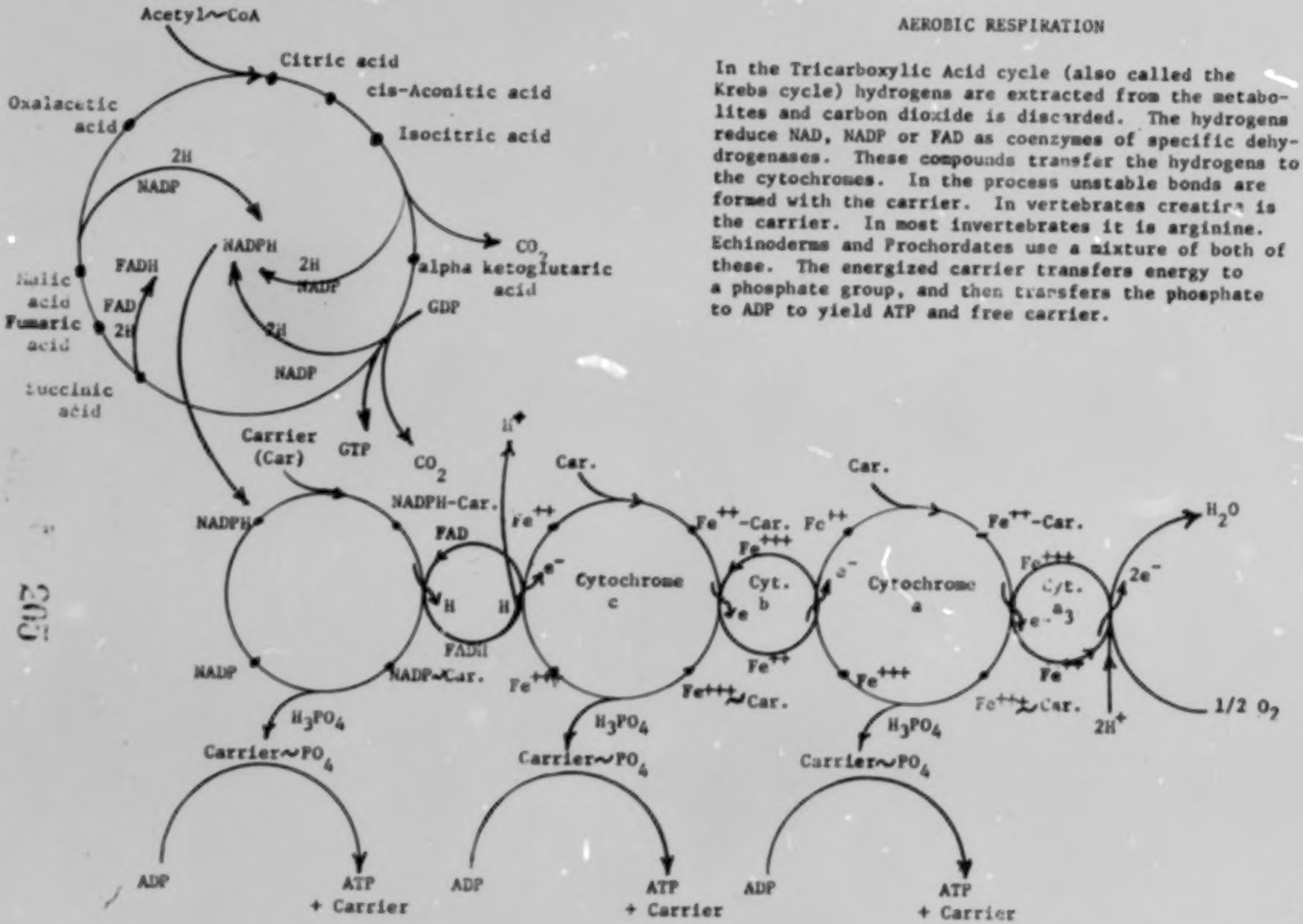
The outlet from pyruvate to other metabolic pathways involves vitamin B_1 (thiamine) which acts to remove carbon dioxide, yielding vitamin B_1-acetate. This in turn reacts with a coenzyme formed from vitamin B_3 (pantothenic acid) and called Coenzyme A (abbreviated CoA), to form acetyl CoA. Acetyl CoA may go on to the aerobic processes of the Krebs cycle, or reacts with itself and carbon dioxide to yield long-chain fatty acids, cholesterol and steroid hormones. The fatty acids react with glycerol to yield the neutral fats (triglycerides).

C. Aerobic Metabolism

The acetyl CoA, so important for the formation of fatty acids, is the key or terminal material linking anaerobic glycolysis (breakdown of glucose) with the aerobic systems. Acetyl CoA reacts with oxalacetic acid to form citric acid, the "first" compound in the cycle of reactions known as the citric acid cycle, or sometimes called for its discoverer the Krebs cycle. Citric acid is degraded in 8 steps to oxalacetic acid again. In the process it gives up 8 hydrogen atoms to reduce NAD (or NADP) to NADH (or NADPH), and discards the two carbons of acetyl CoA as CO_2. Also, a single molecule of guanidine diphosphate (GDP) is phosphorylated to GTP for use in protein synthesis. The function, then, of the Krebs cycle of enzymes is to collect the energized hydrogen atoms of carbohydrates and to discard the carbon dioxide (two components used in photosynthesis), but it takes more than one turn of the cycle to extract all 12 hydrogens contained in a glucose molecule.

AEROBIC RESPIRATION

In the Tricarboxylic Acid cycle (also called the Krebs cycle) hydrogens are extracted from the metabolites and carbon dioxide is discarded. The hydrogens reduce NAD, NADP or FAD as coenzymes of specific dehydrogenases. These compounds transfer the hydrogens to the cytochromes. In the process unstable bonds are formed with the carrier. In vertebrates creatine is the carrier. In most invertebrates it is arginine. Echinoderms and Prochordates use a mixture of both of these. The energized carrier transfers energy to a phosphate group, and then transfers the phosphate to ADP to yield ATP and free carrier.


Acetyl~CoA
Citric acid
cis-Aconitic acid
Isocitric acid
Oxalacetic acid
2H
NADP
NADPH
2H
NADP
CO2
alpha ketoglutaric acid
GDP
Malic acid
Fumaric acid
FADH
FAD
2H
2H
NADP
Succinic acid
Carrier (Car)
GTP
CO2
H+
Car.
Car.
NADPH-Car.
NADPH
FAD
H
H
FADH
NADP
NADP~Car.
Fe++
e-
Cytochrome c
Fe+++
Fe++-Car.
Fe+++
Fe++
Cyt. b
e
Fe++
Fe+++~Car.
e-
Cytochrome a
Fe+++
Fe++-Car.
Fe+++
Cyt. a3
e-
Fe++
Fe++~Car.
2e-
H2O
2H+
1/2 O2
H3PO4
Carrier~PO4
H3PO4
Carrier~PO4
H3PO4
Carrier~PO4
ADP
ATP + Carrier
ADP
ATP + Carrier
ADP
ATP + Carrier

The NADH produced in the Krebs cycle goes to the respiratory chain where it reacts with energy carriers called phosphagens. For vertebrates this carrier is creatine. For invertebrates, it is arginine. For plants it is still undetermined. The NADH--creatine then transfers the hydrogen atom to flavin adenine dinucleotide (FAD--a combination of Vit. B_2-PO_4 and AMP). This leaves the bond between creatine and NAD weakened, so that energy from the molecule flows into the linkage. It is then removed by reacting with phosphate, yielding creatine phosphate and NAD. The NAD is then free to react with more hydrogens in the Krebs cycle. The creatine phosphate reacts with ADP to yield ATP.

The sequence of compounds in the respiratory chain is:

NAD -- FAD -- Cytochrome b -- Cytochrome c -- Cytochrome a -- Cytochrome a_3

ATP molecules are generated (as described above) at NAD, cytochrome b and cytochrome a. Thus, since each hydrogen is responsible for generating 3 ATP molecules in the respiratory chain, the 12 hydrogens of glucose will produce 36 ATP here. When we add the net 2 ATP from anaerobic glycolysis, we can see that each glucose molecule is responsible for the generation of 38 ATP molecules.

In the transfer between FAD and cytochrome b, the hydrogen is split into its proton (H^+), which is released to water in the mitochondrion, and an electron (e^-). The electron is used to reduce the cytochromes. At cytochrome a_3 two protons and two electrons recombine to form hydrogen and an oxygen atom from breathing reacts to form water.

D. Photosynthetic reactions

Splitting of Water and the Light Reactions

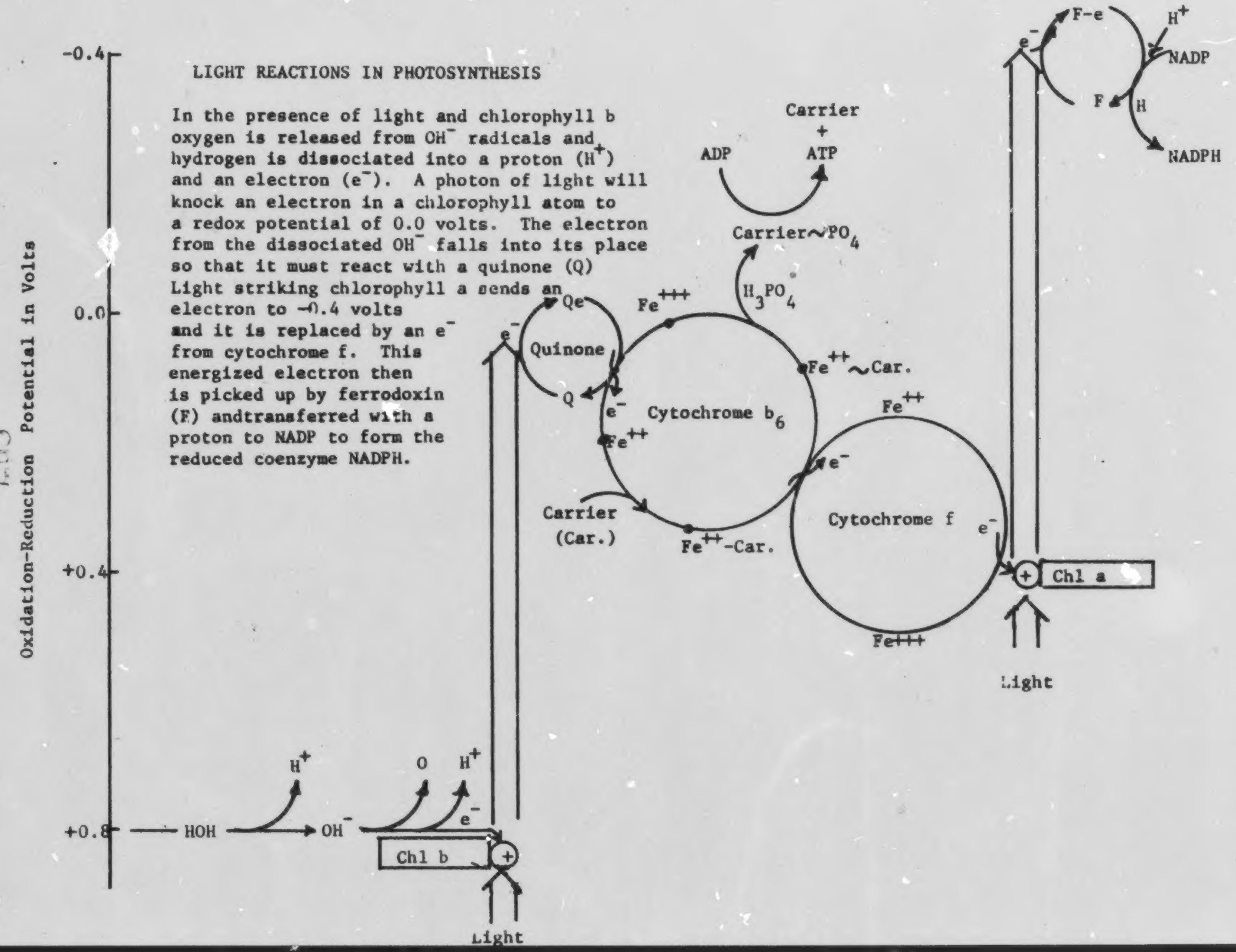
Water normally dissociates into H^+ AND OH^- ions. In the presence of chlorophyll b and light, the OH^- is split apart to yeild an atom of oxygen, which is released as gas, a hydrogen ion, and an electron. In striking the chlorophyll, the packets of light energy (photons) knock an electron in the outer orbit to an orbit farther out. Its place is taken by an electron from water. Since it can not return immediately, this energized electron is trapped by a quinone, such as Q254, and then transferred to cytochrome b_6 where an ATP is generated, then to cytochrome f. At this point in bacteria, it can return to the original chlorophyll molecule. In higher green plants it has an easier reaction. Light strikes a second kind of chlorophyll, chlorophyll a, knocking an electron to an outer orbit. The electron from cytochrome f falls in its place and the energized electron reacts with ferrodoxin. The ferrodoxin then reacts with a proton (H^+) and NADP to yield NADPH, which has the energized electron in the hydrogen.

The Dark Reactions

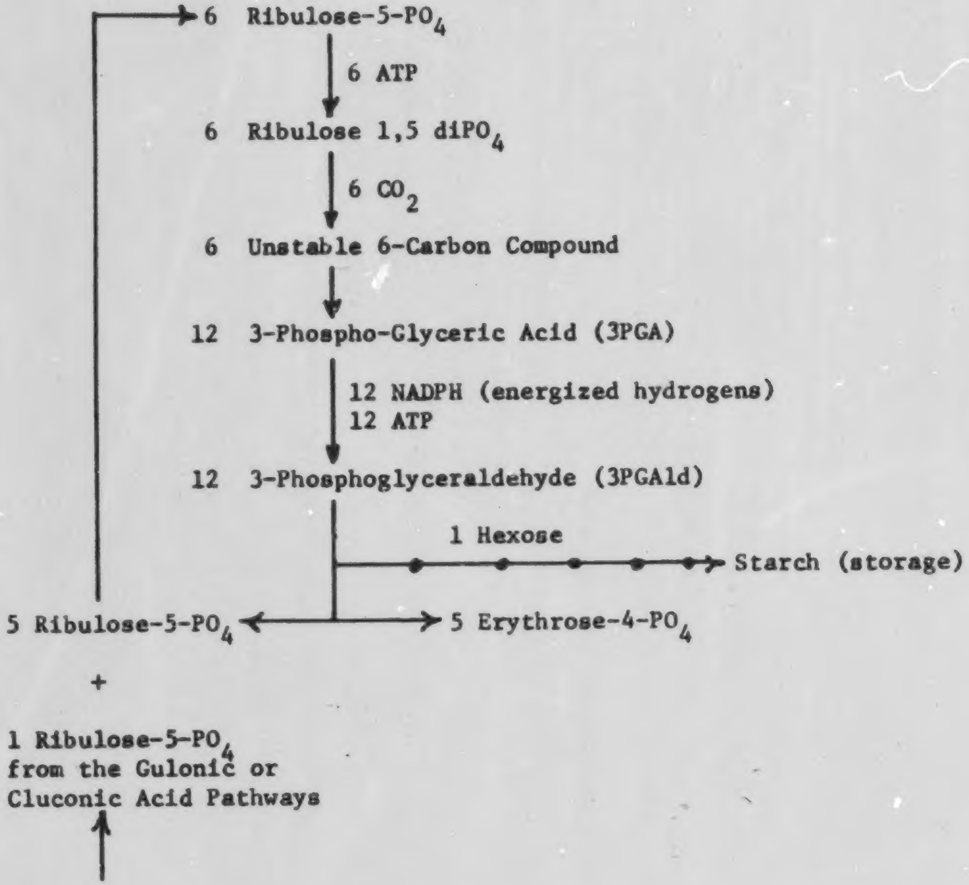
One of the important uses of the roundhouse compound, ribulose-5-phosphate (Ru5P) is in the process of carbohydrate formation. Six molecules of Ru5P

LIGHT REACTIONS IN PHOTOSYNTHESIS

In the presence of light and chlorophyll b oxygen is released from OH^- radicals and hydrogen is dissociated into a proton (H^+) and an electron (e^-). A photon of light will knock an electron in a chlorophyll atom to a redox potential of 0.0 volts. The electron from the dissociated OH^- falls into its place so that it must react with a quinone (Q) Light striking chlorophyll a sends an electron to −0.4 volts and it is replaced by an e^- from cytochrome f. This energized electron then is picked up by ferrodoxin (F) andtransferred with a proton to NADP to form the reduced coenzyme NADPH.


Oxidation-Reduction Potential in Volts
-0.4
0.0
+0.4
+0.8
HOH
H+
OH−
O
H+
e−
Chl b
Light
e−
Qe
Quinone
Q
e−
Fe+++
Fe++
Cytochrome b6
Carrier
(Car.)
Fe++-Car.
Fe++~Car.
H3PO4
Carrier~PO4
ADP
Carrier
+
ATP
Fe++
e−
Cytochrome f
e−
Fe+++
Chl a
Light
e−
F-e
H+
NADP
F
H
NADPH

THE DARK REACTIONS, COMMONLY CALLED CARBON DIOXIDE FIXATION, BUT IT IS IN REALITY ENERGIZED HYDROGEN FIXATION


6 Ribulose-5-PO4
6 ATP
6 Ribulose 1,5 diPO4
6 CO2
6 Unstable 6-Carbon Compound
12 3-Phospho-Glyceric Acid (3PGA)
12 NADPH (energized hydrogens)
12 ATP
12 3-Phosphoglyceraldehyde (3PGAld)
1 Hexose
Starch (storage)
5 Ribulose-5-PO4
5 Erythrose-4-PO4
+
1 Ribulose-5-PO4
from the Gulonic or
Cluconic Acid Pathways

react with 6 ATP to yield 6 Ru 1,5-diphosphate (Ru 1,5P). The six molecules of Ru 1,6P then react with 6 CO_2 to yield 6 molecules of a 6-carbon complex. This breaks down into 12 molecules of phosphoglyceric acid (PGA). The 12 PGA react with 12 ATP and 12 NADPH from the light reaction and is reduced to 12 molecules of 3-phosphoglyceraldehyde (3PHGA1) which forms 6 molecules of fructose-6-phosphate (F6P). Five of these F6P go through the non-oxidative path back to ribulose-5-phosphate, and the 6th goes on to form either sucrose (transport form of sugar in plants) or to be stored as starch or cellulose.

In summary, the light reactions involving chlorophyll are concerned with the formation of energized hydrogen atoms, which are trapped in NADP as NADPH, and the generation of some ATP. These products are used to reduce carbon dioxide which has been attached to the highly energized Ru 1,5P. In this way the energy of sunlight is captured for the use of living plants and animals.

In glucose metabolism (see preceeding sections) the process is reversed. The hydrogens are removed in the Krebs cycle and the carbon dioxide discarded. The energy in hydrogens is then released for ATP formation and finally water is produced, which can be split again for photosynthesis.

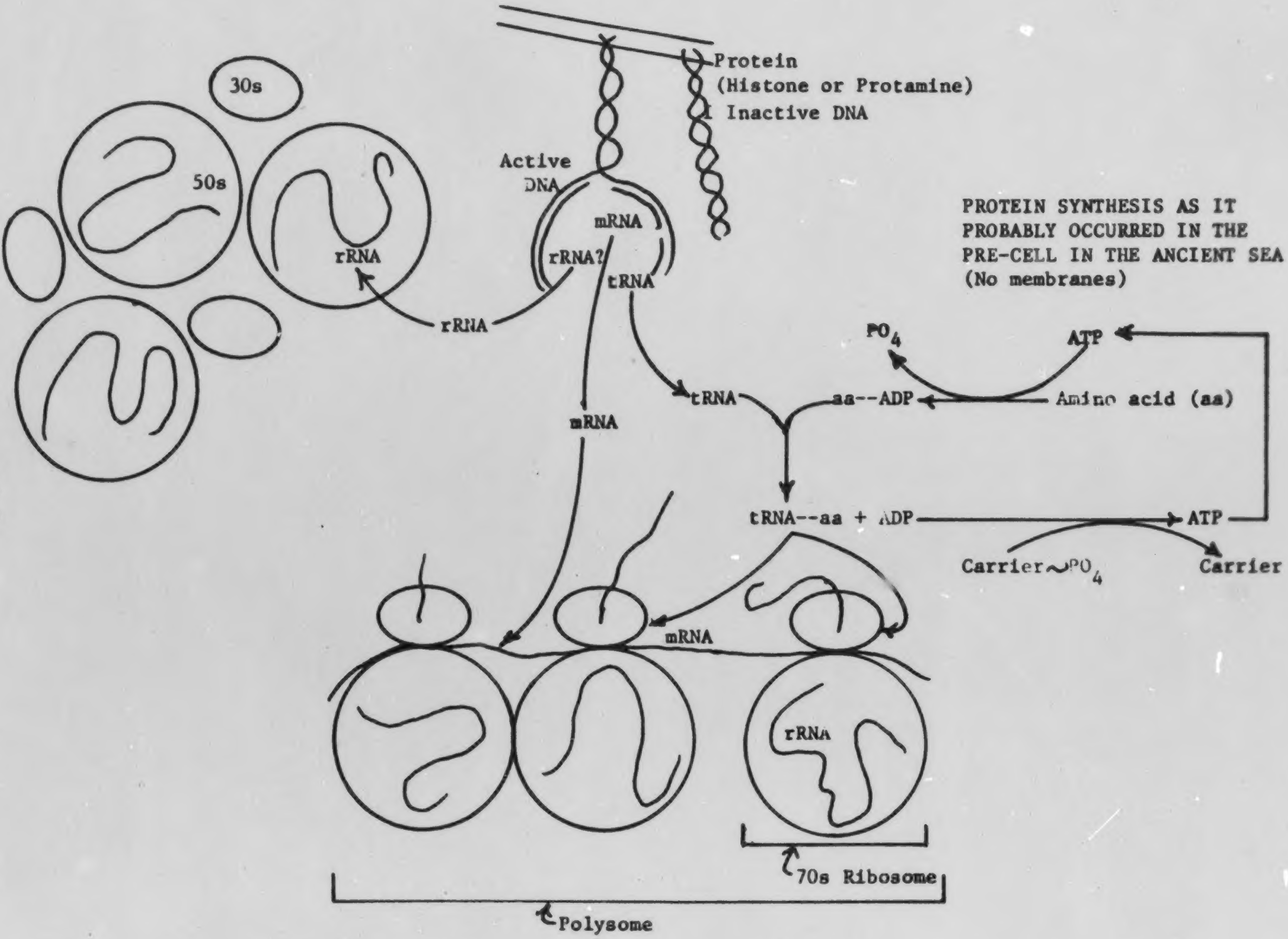
Therefore, hydrogen is the ultimate fuel of the cell.

E. Protein Synthesis

We have indicated previously that the sequences in DNA were originally ordered by the proteins. Once established, the DNA not only can replicate its own sequences, but make other kinds of nucleic acids (r-, m-, and t-RNA). The nucleic acids are only made during interphase of the cell. During cell division all production stops.

In the ancient oceans there were no cell membranes -- in the days of the pre-cell when these chemical processes became established. That doesn't matter, the bacteria (eubacteria) don't have any membrane around the chromosome material even today. The amino acids reacted with ATP to form energized amino acid--ATP compounds. These reacted with transfer RNA produced by the DNA from nucleotides containing ribose. This yielded tRNA--amino acid complexes, with ADP released into the medium. Ribosomes formed in the nuclear area (no distinct nucleolus is seen in bacteria) are released into the pre-cell community of molecules. As some metabolites (substrates) became low in supply, certain parts of the DNA (genes) were stimulated to form another kind of RNA, messenger RNA. The messenger RNA is attracted to the ribosomes. Sometimes it is strung across two to five or six of them (polysomes). Ribosomes are produced in two sizes of sub-units which we characterize as 30S and 50S (see page). These work together to form a 70S functional ribosome. The messenger RNA goes on the larger 50S ribosomes. The smaller 30S ribosomes act as "tape readers" and correlate the sequence of nucleotides on the messenger RNA with certain nucleotide sequences on the transfer RNA. This brings the tRNA with the appropriate amino acid into place and enzymes on the ribosome link the amino acid with the last one attracted. In this way short chains (peptides) and then longer chains (proteins) of amino acids are linked by the 30S ribosomes and the sequences on the messenger RNA see to it that the amino acids are put together in the exact sequences that make the specific protein involved. As a matter of principle, there is one gene (DNA) for each specific protein. Therefore, it takes a whole set of genes to get a whole set of proteins which make up a cell or the cells of an organism.

PROTEIN SYNTHESIS AS IT
PROBABLY OCCURRED IN THE
PRE-CELL IN THE ANCIENT SEA
(No membranes)


30s
50s
rRNA
rRNA
Active DNA
Protein
(Histone or Protamine)
Inactive DNA
mRNA
rRNA?
tRNA
mRNA
tRNA
aa--ADP
PO$_4$
ATP
Amino acid (aa)
tRNA--aa + ADP
ATP
Carrier~PO$_4$
Carrier
mRNA
rRNA
70s Ribosome
Polysome

II. Cell Activities Related to Cell Functions

Specific References
Florkin (1960)
Holter (1961) *Scientific American reprint*
Kimball (1970), pp. 81-88.
Oparin (1953)
Wald (1954) *Scientific American reprint*

Teacher Reference
Florey (1968)

A. Formation of the Cell

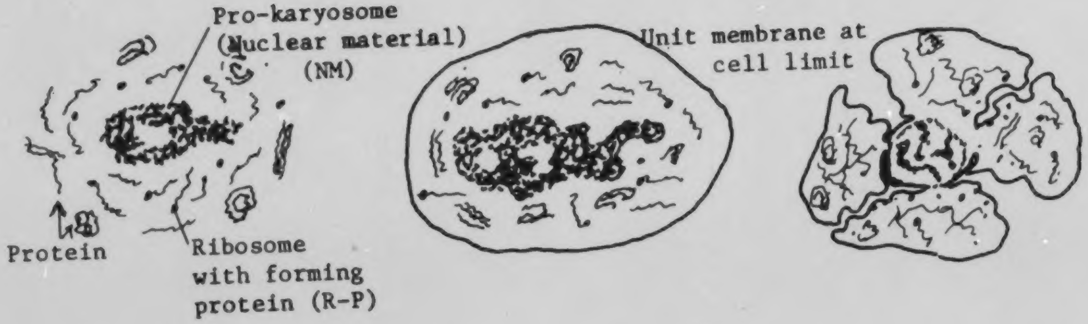
1. The Pre-Cell Transformed to a Real Cell

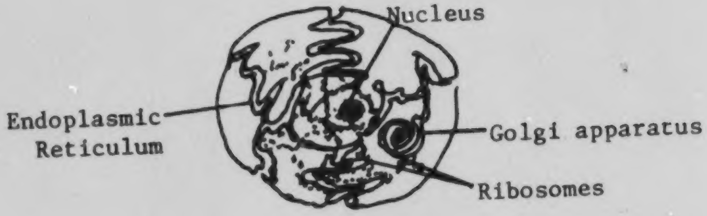
The pre-cell carried on anaerobic metabolism and reproduction. We cannot tell about mitochondria very well. It is clear that the enzymes systems in mitochondria, the Krebs cycle and the respiratory chain, are different enzymes than those generally available in the cytoplasm. The same is true of chloroplasts. We do know, that in bacteria and the lower algae there are no mitochondria but granules containing the respiratory enzymes, just as there are no chloroplasts, but instead, the cell is filled with the photosynthetic membranes which in the chloroplasts form the grana and intergrana. Anaerobic metabolism comes down to pyruvate and then shifts to one of the final fermentation products. It is possible that the aerobic system was also formed in the same way as the anaerobic system, but because oxygen was not available at first, the aerobic systems came up to cytochrome a_3 and stopped.

Was there cell division? That is another question that has no clear answer. If there was no membrane it seems doubtful that there was a reason for the community of nucleic acids and enzymes to "divide" as we think of that idea. We can imagine that each protein strand had its associated group of nucleic acids--tRNA, mRNA, perhaps rRNA, and DNA containing the stable gene. Ribosomes may also have been in existence early, since they occur in bacterial cytoplasm (but not attached to a membrane because there was no membrane to be attached to).

(See diagram on the next page)

If we take our cues from the bacteria and blue-green algae, the nucleic acids, especially the DNA must have begun to aggregate in a central area. A possible mechanism would be that nucleotides near the DNA would be used for making new DNA and RNA, leaving the concentration nucleotides low there. This


Pro-karyosome
(Nuclear material)
(NM)
Protein
Ribosome
with forming
protein (R-P)
Unit membrane at
cell limit


Nucleus
Endoplasmic
Reticulum
Golgi apparatus
Ribosomes

would set up a gradient for nucleotides, attracting free ones from elsewhere in the pre-cell community to the area of DNA. Eventually the nucleotide-forming function and DNA synthesis would be combined and the pre-nucleus (pro-karyon) was formed. The pro-nucleus formed ribosomes, sending them into the community, and later, the messenger RNA, as the need arose to increase the amount of any particular enzyme. Taking our cue from bacteria, the plasma membrane first enclosed the outside part of the cytoplasm, then invaginated and spread around the nuclear material, forming the nuclear envelope, but permitting communication between the nuclear sap and the cytoplasm.

2. The Structure of the Membrane

The cell membranes all have the same structure. It is relatively simple, but extremely well-organized to carry out its functions. The membrane is about 75 Å thick. The layers are diagrammed below. Various descriptive names have been applied--bimolecular leaflet, although there are obviously more than two molecular layers. Even such a description, which is very appropriate for electron microscopic observation as a "three layered" membrane is not entirely adequate. The term unit membrane is the best, because all the membranous structures of the cell are made of this membrane which has a common structure.

Although the membrane behaves sometimes as though it had holes in it, there are no visible holes (even with the electron microscope).

(See diagram on the next page)

Demonstration and Approach

Take a fair-sized balloon and inflate it "softly", that is, so that there will be some elasticity for poking some fingers toward the center of the sphere. Do just that for the class, to demonstrate the continuity of the external part of the cell membrane, the endoplasmic reticulum and the nuclear envelope.

Also, point out that the wall of the balloon does not determine the shape of the cell, but the air inside. That is an exact parallel of the shaping of living cells. The outside membrane is too thin to give shape to the cell, instead, the cytoplasm within, particularly the layer next to the membrane (about 1-2 microns thick) called the cell cortex, provides the shape for the cell.

Lastly, point out there are some differences between the unit membrane of the cell and the balloon. When fingers are withdrawn from the balloon, it returns to its original shape (elasticity). The cell membrane tends to stay put, that is, instead of stretching the membrane inward, the membrane grows inward.

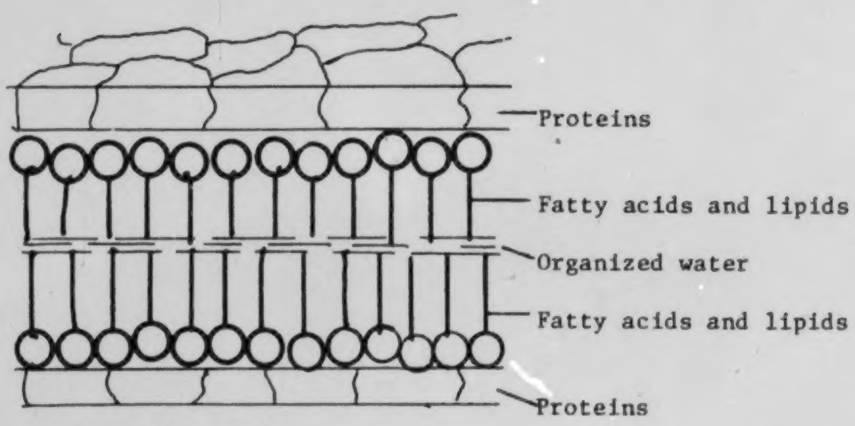

Proteins
Fatty acids and lipids
Organized water
Fatty acids and lipids
Proteins

Diagram of the molecular arrangements in a segment of cellular unit membrane. Average thickness is about 75 Å.

Also, the membrane can be self-healing for small injuries, so that it can pinch off during cell division. Nuclear membrane fragments adhere to chromosomes during cell division. The membrane can survive being punctured by minute electrodes (up to about 1 micron diameter), etc. Such a prick would burst a balloon.

Ask students about these differences between the cell membrane and a rubber balloon.

Have one or more students come to the chalkboard and diagram the layers in the plasma membrane as they remember it from their reading. Correct errors.

3. Permeability

Claude Bernard advanced the idea of the constancy of the environment in the mid-19th century. The concept is that a constant environment is needed for a constant function. An organism must adapt to a changed environment, if it can. If not, it will die.

A non-living membrane with small holes in it acts as a sieve. It can be used to contain some large molecules while letting some small ones pass in and out. Cellophane and other synthetic plastic membranes are of this type. They are referred to as being "semi-permeable", that is, permeable to the solvent, but not the large molecules of solute.

a. Four Old Theories of Cell Membrane Permeability

1) The Sieve Theory held that the membrane acted as a sieve, but experiments showed that there are many larger molecules that pass through more easily than some smaller ones. Therefore, the cell membrane does not always act as a sieve.

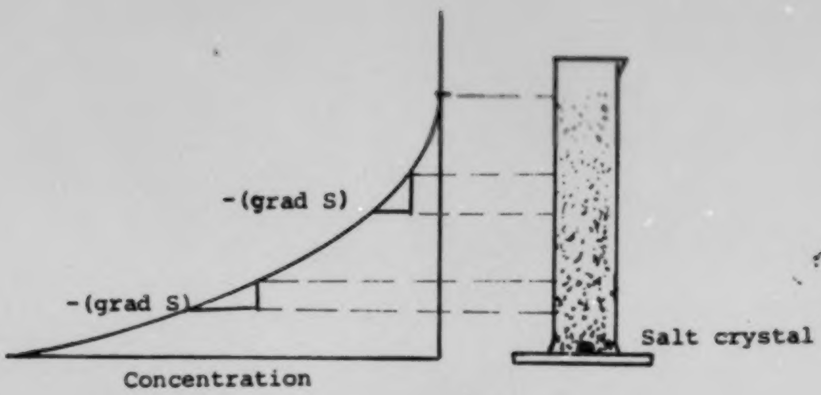
2) Lipoid Solubility Theory held that since some lipid solvents, such as ether, chloroform, alcohol, and similar substances, go through the membrane fairly easily, the membrane was mainly lipid. But, the membrane also has proteins.

3) The Molecular Theory was based on the fact some molecules go across the membrane more easily than ions. For example, vinegar (acetic acid) ionizes poorly, but is much more sour to the taste than HCl, which is almost completely ionized.

4) The Adsorption Theory held that materials were attached to large lipid micelles which moved on their centers to bring that which was outside, inside.

b. Diffusion

If a gaseous substance (such as perfume) is left open in a room, its fragrance begins to diffuse through the air. Soon after opening the bottle it can be smelled near the bottle but not in the farther reaches of the room. After a while the perfume pervades all the air of the room. This process of one substance moving through another, as in a mixture of ideal gases, is called diffusion. Diffusion also occurs if a crystal of a soluble salt is carefully placed in the bottom of a container of solute, such as water. After a short time, if we measure the concentration (by the color intensity if a colored salt is used) we would find the concentration graded away from the crystal. Such a grade is called a gradient.

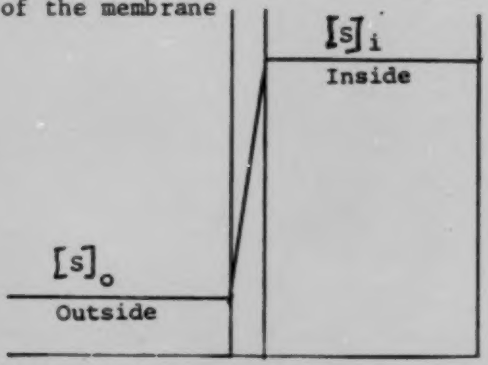


We may designate the concentration gradient for a substance S as being -[grad S] as we move away from the higher concentration. The flux is the net movement away from the crystal. The rate at which a substance moves through the solvent is a constant, the diffusion constant (D_s) for substance S. So

the rate at which substance S moves through the water is represented as -[grad S]D_s.

If the solute S is in high concentration on one side of a membrane and low on the other, then the whole difference occurs within the membrane of thickness d. The movement of the solute is the result of kinetic activity of the water. An average membrane may be 100 Å thick (d), so that we may represent the ability of the solute to pass the membrane (its permeability) as

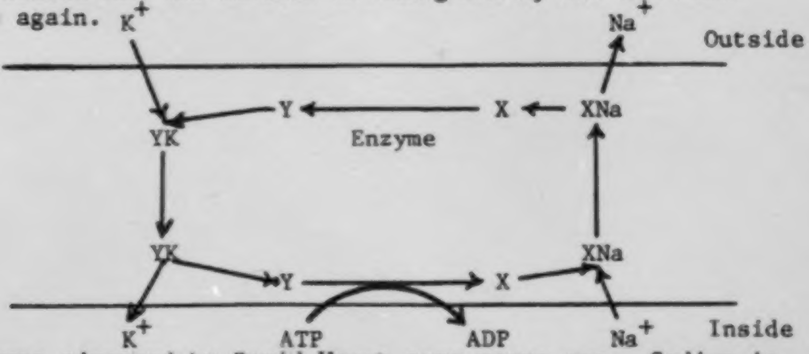
Where $[S]_i$ is the concentration on the inside of the membrane and $[S]_o$ is the concentration on the outside of the membrane



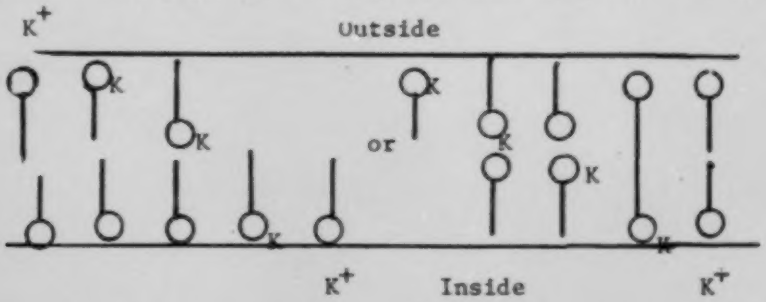
The diffusion constant for Na^+ is about 1cm./sec. in water, and about 10^{-7} cm. in frog gastrocnemius membrane, so that the membrane slows down the passage of sodium ions diffusing through about 10 million times the rate in 100 Å of water. Therefore, the membrane is a very effective barrier to the ion.

c. Two Current Theories of Membrane Transport

1. Thermal Diffusion. This group of theories stem from the one advanced by Shaw and Glynn in 1957. A carrier, now shown to be phosphatidyl serine (X), or other combinations of amino acids, such as arginine, and phospholipid, such as lecithin (which is a normal component of the membrane) is energized by ATP. It picks up sodium on the inside of the membrane and diffuses with it to the outside where it is released. The carrier is then slightly modified by an enzyme which makes it have affinity for potassium ions (Y). They attach on the outside of the membrane and are carried acorss by the carrier to the inside, where they are released and the carrier is energized by ATP and made attractive to sodium ions again.



2. The flip-flop theory was advanced by David Waugh some years ago. Sodium is attached to the polar group on a fatty acid in the cell membrane. This changes its charge and it flips over and either transfers the ion to the next layer of lipid (which flips), or sinks down to the second layer and flips over. The ion is then released, the whole process taking not more than 10^{-8} seconds.



This ability of the membrane to pick up ions and transport them across, usually against a concentration gradient, is work, and therefore, requires energy. There are two components to this work, one is osmotic--that is the work necessary to move a mole of say K ions across the membrane against the gradient. This separation of ions by non-electric means creates a battery, so that the voltage trying to discharge across the membrane (electrical work) just counterbalances the osmotic work being done by the membrane.

The Nernst equation is applicable for computing the electrochemical potential across the membrane, commonly called the transmembrane potential or transmembrane voltage (E_m). The value in millivolts for any particular ion, for example, potassium (E_k), is given by the formula:

$$E_K = RT/Z_K F \ln [K]_o - [K]_i$$
$$= RT/Z_K F \ln [K]_o/[K]_i$$

RT is the gas constant and the absolute temperature, F is a faraday, the electrical charge in 1 mole of ions. The conversion factor from ln to $\log_{10}$ is .2303, so that the expression RT/F at 37°C. is 60, and we may write

$$E_K = 60 \log_{10} [K]_o/[K]_i \text{ mv}$$

Z is the valence of the ion under consideration. For potassium it is 1. Let us take a case where the concentration of potassium ions is just ten times greater inside the membrane than outside. We substitute these values, viz:

$$E_K = 60 \log [1]/[10]$$

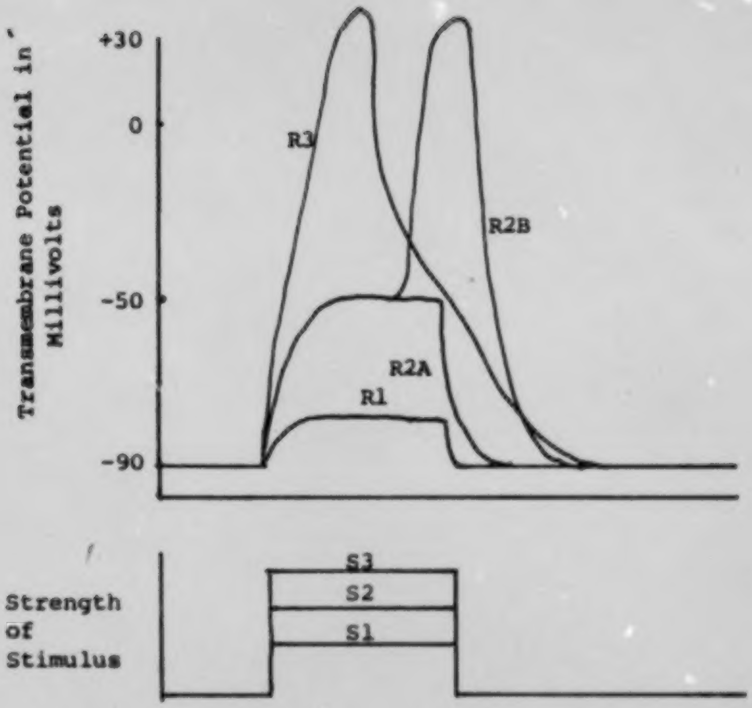
The $\log_{10}$ of $1/10 = \log .10 = -1$ so that

$$E_K = 60 (-1) = -60 \text{ mv.}$$

Because of this active transport of ions, essentially the transport of sodium ions out of the cell and the passive replacement of them by potassium ions, we find that the membrane is charged, positively on the outside (where the sodium ions are) and negatively on the inside (where most of the potassium ions are). If a very fine electrode (0.5 micron in diameter) is pushed through the membrane, the transmembrane voltages can actually be picked up, amplified and displayed on a galvanometer or oscilloscope. Most animal cells have an E_m of about -90 mv. on the inside of the membrane.

Stimulation of the membrane by mechanical, electrical, chemical or osmotic means will change the ion balance across the membrane and consequently the transmembrane voltage. That is, the sodium pump is partially reversed until an E_m of about -50 mv. is reached. At this point (threshold) the pump reverses itself, pumping sodium ions into the cell until the inside voltage is about +40 mv. It then resumes its normal pumping direction and pumps and sodium ions out until the normal resting potential (-90 mv.) is again reached. This series of changes is called an impulse. The voltage at the impulse is called the action potential, and is propogated in all directions over the cell membrane.

These relationships are diagrammed on the following page. S = stimulus, R = response.

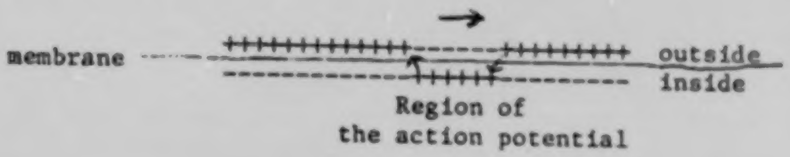


S1 is called a subthreshold (subliminal) stimulus and it will only evoke a local response (R1), that is, a change in E_m which is not propogated.

S2 is a threshold stimulus. It is borderline so that sometimes it may only evoke a local response (R2A), but sometimes this same stimulus will evoke an action potential (R2B), which is propogated.

S3 is a submaximal stimulus, which reverses the ion pump immediately and creates a propogated action potential (R3).

The charge along the membrane of a long cell (muscle or nerve fibers) would be:



d. Osmosis. Diffusion as a phenomenon does not need a membrane. Diffusion, of course, may occur through membranes. Osmosis, on the other hand, requires a membrane so that solute molecules can be held in a somewhat restricted locale.

Essentially the process is like the diffusion of a gas through a gas, where each finally exerts a partial pressure proportional to its fraction of the mixture. If there is a mixture of gelatin and water on one side of the membrane (inside of the dialysis bag, or of the cell) and only water on the other side, then the amount of water per ml. is less in the gelatin solution because the gelatin molecules occupy some of the volume. The diffusion pressure, therefore, is the attraction of this "water vacuum" for water. It will continue until either the hydrostatic pressure (or, the turgor pressure) equals the diffusion pressure. At that point the system has reached osmotic pressure. The osmotic activity is a function of the number of particles in the solution. See the Teacher's Guide to Exercise 12--Diffusion, Osmosis and Active Transport.

Approach and Demonstration

Approach to Diffusion, Permeability and Active Transport

Since these ideas will be rather abstract for the student, begin by doing Exercise 12--Diffusion, Osmosis and Active Transport in Laboratory Activities for Biology.

Obtain a bottle containing a small quantity of a good perfume and open it, perhaps pour some into a clean beaker for a while (and then you can pour it into the bottle. The fragrance will diffuse through the room. Incense can also be used instead of perfume.

Place a large crystal of copper sulfate or of cobalt chloride in a 100 ml. graduated cylinder. Gently pour water down the side of the graduate while it is held on an incline. Let stand a few minutes. The class may watch the diffusion during the period and the completed situation the next time they come to class.

Foods get into cells. Of course! That's where they get the energy to run on. Ask the class how they think that materials get across the membrane, especially since it doesn't seem to have any holes in it. Have some students diagram their ideas on the board. Then present the information on Permeability (above).

Ask students what their ideas are about "active transport". They will no doubt say that it is transport with the aid of energy against a concentration gradient. Then ask how do they think energy is used to transport the materials.

B. Shapes of Cell Parts and Their Roles

Specific Reading:
Swanson, *The Cell*, pp. 10-31.
Kimball, *Cell Biology*, pp. 52-70.

Alternate Readings:
Simpson and Beck, *Life*, pp 44-63.
Brachet, "The Living Cell", *Scientific American*, September, 1961.

Teacher References:
Fawcett, *The Cells*.
Gerald, *Unresting Cells*.
Hurry, *The Microstructure of Cells*.
Loewy and Siekevitz, *Cell Structure and Function*.
Parker, et al., *The Structure and Function of the Cell*.
Pfeiffer, *The Cell*.

1. Protein forms and their relationship to viscosity.

(See Teacher's Guide to Exercise 8 and 10)

When proteins are in the secondary form (that is, balled-up or folded-up) they slip past each other easily and therefore, form *hydrosols*, or simply *sols*. When they are extended in their tertiary form they do not slip past each other easily. They form a gelatinous mass called a *hydrogel*, or simply a *gel*. Familiar material behaving this way is dessert gelatin which is a *sol* when warm and a *gel* when cool.

The cytoplasm, and some special parts of it, behaves as it does because of its proteins. The *cell cortex* is a region 1-2 microns thick just under the external cell membrane. It is a *gel* and gives shape to the cell. Asters and spindle fibers are also gelatinous structures made up of extended proteins which fold up after cell divion processes are completed. (See part 4 of this section). The main part of the cytoplasm, the endoplasm, is made up of both folded and unfolded protein so that it has a viscosity about that of glycerine (glycerol).

2. Membranous Structures

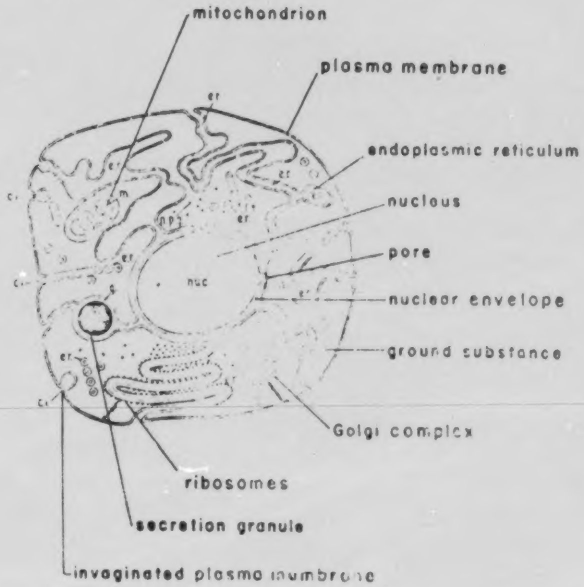
a. Cell Limit - It is better to refer to the outer portion of the cell membrane as the cell limit. Partly because it may not be clear to the student at this point that the cysterni of the endoplasmic reticulum and nuclear membrane are just as much "outside" of the cell as the part external to that which used to be called *the* plasma membrane. When looking through the microscope one also sees the cell cortex and some external protective gum which stains. The plasma membrane itself is only 75 to 100 Å, which is too thin to be seen by visible light, since light microscopes do not resolve less than 5000 Å (.5 micron), as a rule. However, the cell limit is easily resolved.

Begin by drawing the outline for a cell leaving ports for the ER.

b. Endoplasmic Reticulum (ER)

The infoldings of the external membrane that reach through the cytoplasm (endoplasm) is called the endoplasmic reticulum (ER) (reticulum = network). The spaces between the two unit membranes are called cysterns and are part of the external environment of the cell--that is, the cysterni are not within the substance of the endoplasm. Materials in the cysterni are transported across the membrane (ER) by methods already discussed under membranes.

Extend the representation of the ER to form the nuclear envelope, leaving ports between the nucleoplasm and the cytoplasm. Include the golgi apparatus one one ER channel.



c. The Golgi apparatus was first discovered by Dr. Golgi in 1895. It seems to have more lipid than the rest of the membrane so it is also known as the liposome. It is especially permeable and it is here that materials to be removed from the cell are packaged in membranes before being released. It frequently appears coiled in the EM but may also be a stack of plates in some cells.

d. The Nuclear Envelope (Nuclear membrane)

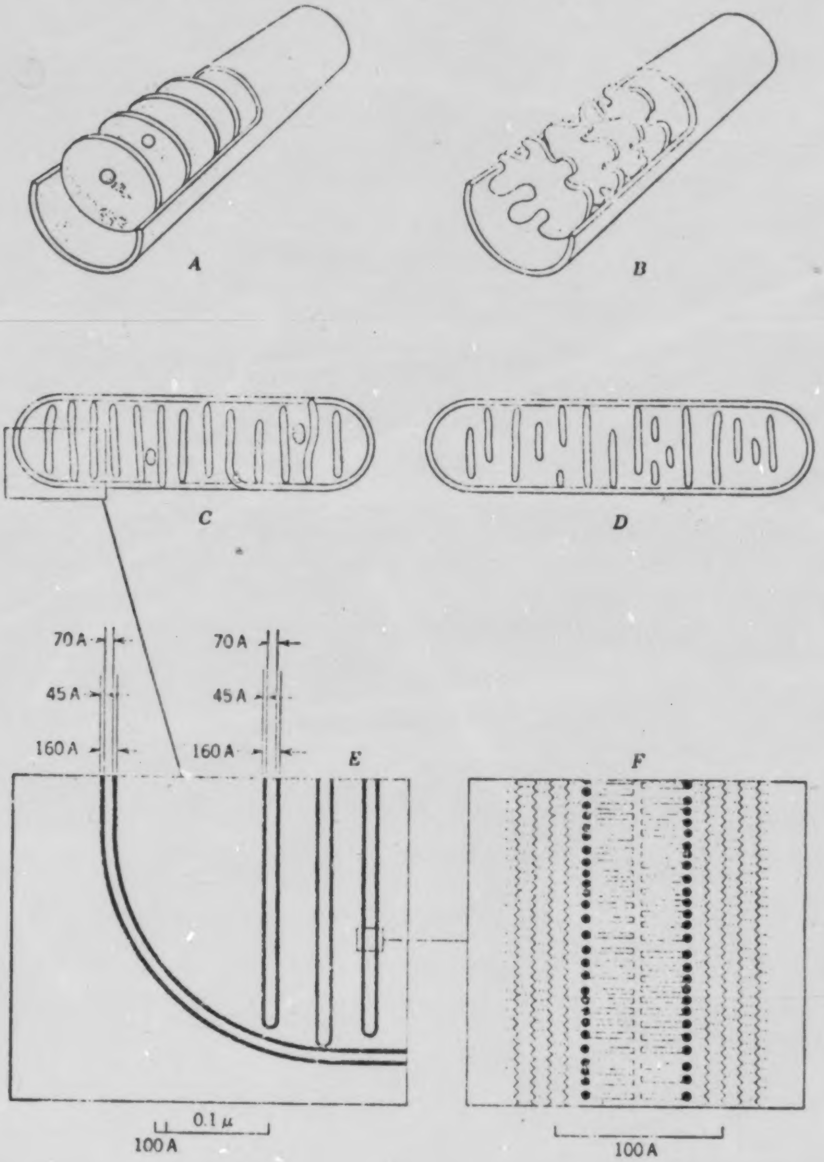
The nuclear envelope, where it exists, is an expansion of the ER. Thus, the nuclear material, which originally was part of the environment (as was the endoplasm) is kept in close association with at least a modified "outside", even though it may be near the center of a cell.

e. Vacuoles.

Vacuoles are formed when phagocytosis, pinocytosis, or diffusion inward require the storage of some materials outside of the cytoplasm. The external membrane, or even the ER, may pinch off (easily healed contact separation). This is close contact with the inside. Vacuoles are usually surrounded by mitochondria because the materials (enzymes, etc.) must be secreted into the vacuole, and the products removed for cell use. Vacuoles are found in lower animal (Protistan) cells and in nearly all plant cells but not in healthy Metazoan cells, as a rule.

f. Mitochondria

Since some primitive cells (bacteria) have the enzyme systems of mitochondria, but not the membranous structure, we may assume it arose in cells. The real function of cell membranes is to compartmentalize the varied cell activities. The activity of the respiratory enzyme systems increased because the enzymes (systems) are arranged as "lollipops" on the inner membrane. They (the enzymes) are apparently produced in mitochondria since an intrachondral body, seen with the EM, has been found to contain DNA. Mitochondria may break up into granules, or coalesce into elongate structures.



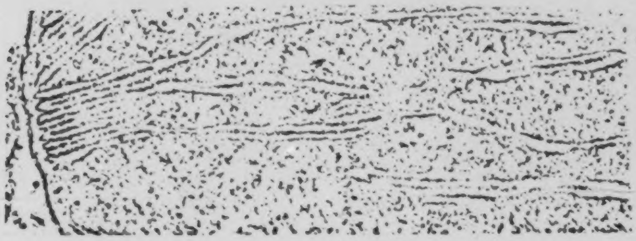
Schematic drawing which illustrates an interpretation of the three dimensional appearance of the mitochondria and of the molecular architecture of the mitochondria membranes. The three dimensional representation *A* and *B* is based on an interpretation of the patterns observed in sections which can be, for instance, like the ones shown in *C* and *D*. *E* gives some commonly observed dimensions of the mitochondrial membranes, and *F* a scheme of the proposed arrangement of lipid and protein molecules in the membranes [from F. S. Sjostrand, in *Fine Structure of Cells*, Proc. Symp. VIII Cong. Cell. Biol., Leiden, 1954 (Noordhoff, Ltd., Leiden, 1955), p. 16].

The mitochondrial enzymes metabolize acetyl CoA to collect the hydrogens and discard the carbon dioxide. The energy of food (glucose, fats, proteins) is in the hydrogens. The respiratory chain enzymes extract this energy in three steps and transfer it to a carrier and thence to ADP. For each glucose, 2 acetyl-CoA are formed and the 12 hydrogens are oxidized to water, yielding 36 ATP molecules whose energy is used for the osmotic, mechanical, synthetic and transport work of the cell.

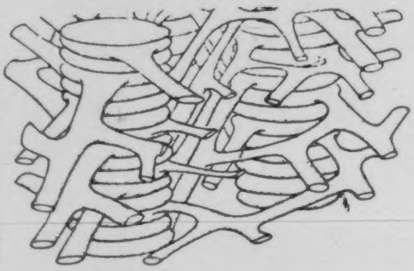
g. Plastids

There are several types of plastids, but there isn't any doubt but that the green ones (chloroplasts) containing chlorophyll are the most important.

In the bacterial and blue-green algal cell, the whole cell is the chloroplast.



A portion of a chloroplast showing the arrangement of the membranes in the grana and intergranal membranes. The small dense particles in the stroma are ribosomes of the chloroplast. Magnification 78,000. (Courtesy of Dr. Myron C. Ledbetter.)



A schematic representation by Dr. T. E. Weier of the membranes in a tobacco chloroplast showing the stacks of membranes in the grana and the intergranal connections. (From Weier, T. E., Stocking, C. R., Thomson, W. W., and Drever, H. J. *J. Ultrastruct. Res., 8,* 141 [1963]. Copyright Academic Press, reprinted by permission.)

It is the same as a unit membrane with 2 changes. Chlorophyll substitutes for fatty acid on one side and there are fatty acid semi-conductors between the two sides of the membrane.

The chloroplast and other colors of plastids have this organization:

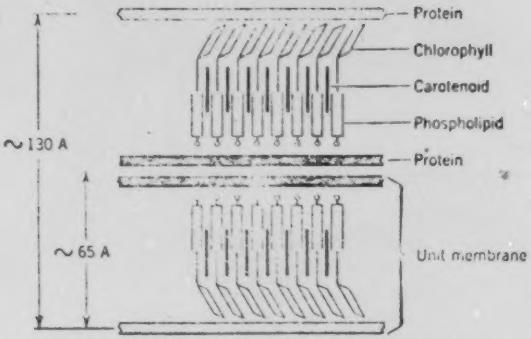
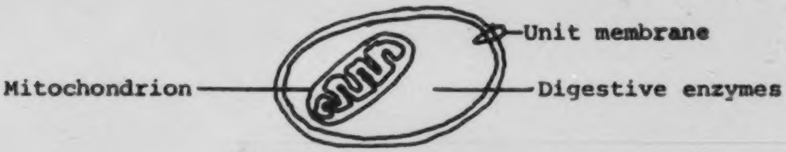


FIG. 12. Diagram to illustrate one way in which the compound lamellae observed in electron micrographs of chloroplasts could be built up from structurally asymmetric unit membranes having a molecular structure of the type proposed by Calvin

h. Lysosomes

Lysosomes are analogous to digestive vacuoles in protozoan cells for they enclose enzymes in a membrane--but they are passive digestive enzymes--pepsin, trypsin, chymotrypsin, and other enzymes found also in the digestive tract. If the cell becomes "sick", the inhibitors that protect the lysosome membrane are lost and the enzymes digest their way out. These "built-in booby-traps" then proceed to digest the cell and the foods produced are absorbed and used elsewhere.

Here is one illustration of their use. If a tired animal dies (has converted all cell glycogen to lactate), rigor mortis sets in quickly. If nothing else is done, after a few days the rigor leaves because lysozymes have done part of their work.



i. Peroxisomes

These are membrane-enclosed vesicles containing dense granular, or sometimes crystalline material. They function in the destruction of harmful hydrogen peroxide.

$$2\,H_2O_2 \xrightarrow{\text{Peroxidase}} 2H_2O + O_2$$

(See Loewy and Siekevitz, 1963 (sec. edition) pp. 76-77)

j. Microbodies

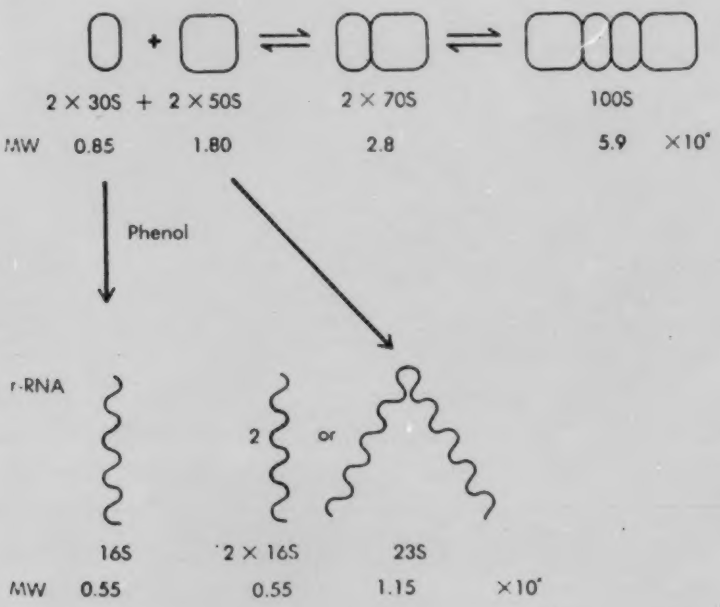
Function not yet understood. May be concentrates on enzymes.

3. Particulate Structures (not bound by membranes)

a. Nucleolus

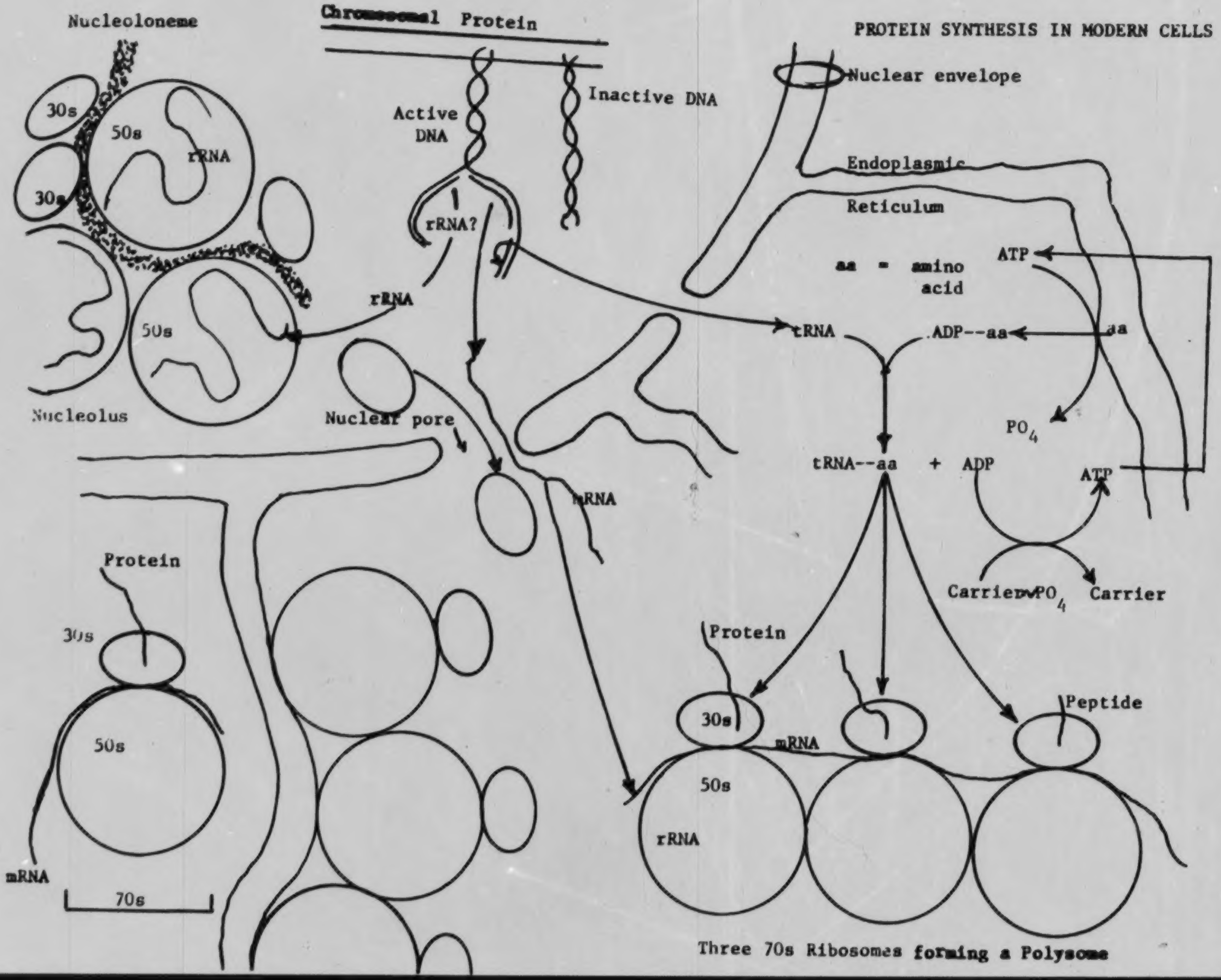
This structure in the nucleus accumulates protein and rRNA for the production of ribosomes. The organizing structure is threadlike and therefore, called the nucleoloneme (neme thread (Gr.). The completed ribosomes migrate into the cytoplasm, although some may produce the histones and protamines (both are kinds of proteins) which combine with DNA in chromosomes. These proteins appear to regulate the activities of genes.

Two sizes of ribosomal particles are formed. These have sedimentation rates in the ultracentrafuge of 30S and 50S. These combine to form these sizes and shapes:


2 × 30S + 2 × 50S
2 × 70S
100S
MW 0.85 1.80 2.8 5.9 $\times 10^6$
Phenol
r-RNA
2
or
16S
2 × 16S
23S
MW 0.55 0.55 1.15 $\times 10^6$

The nucleolus is large in cells making a lot of protein, and small in synthetically sluggish cells.

PROTEIN SYNTHESIS IN MODERN CELLS


Nucleoloneme
30s
50s
rRNA
30s
50s
Nucleolus
Chromosomal Protein
Active DNA
Inactive DNA
rRNA?
rRNA
Nuclear pore
mRNA
Nuclear envelope
Endoplasmic
Reticulum
aa = amino acid
ATP
tRNA
ADP--aa
aa
PO4
tRNA--aa + ADP
ATP
Carrier~PO4
Carrier
Protein
30s
50s
mRNA
70s
Protein
30s
mRNA
50s
rRNA
Peptide
Three 70s Ribosomes forming a Polysome

b. Ribosomes and Polysomes

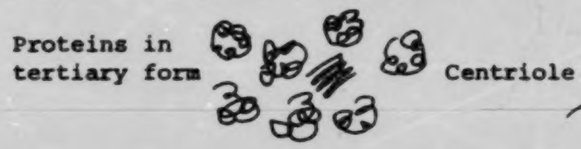
See Section I of this unit on protein synthesis and compare the diagram for the cellular synthesis of proteins with the one on page

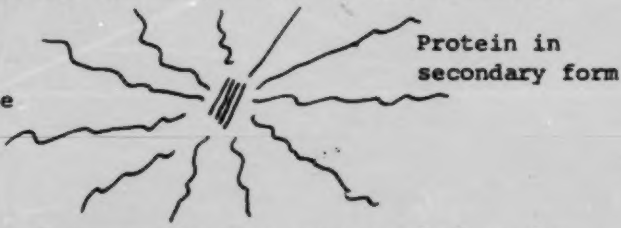
The ribosomes may associate with each other in the cytoplasm to become polysomes or they may come to rest on the source of the amino acid supply, the ER, especially in the basal part of the cell, which is the end in which the raw materials (foods) are most abundant.

4. Fibrous--Amorphous and Fibrous--Fibrous Structures

a. Centrosome and Asters

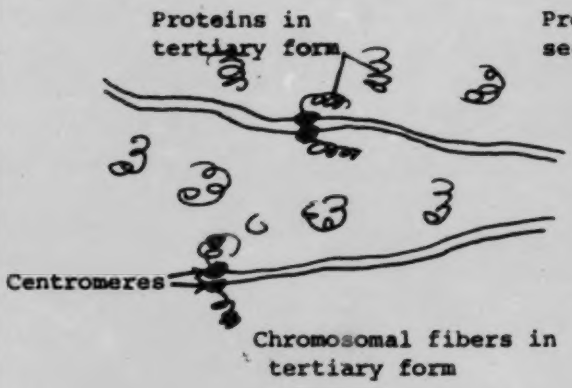
The centrioles in the metabolic cell lie in a region of "modified cytoplasm". Actually the proteins are in the **tertiary** form. When the nuclear membrane disrupts at cell division, changes in pH and salinity cause these proteins to extend to their **secondary form.**

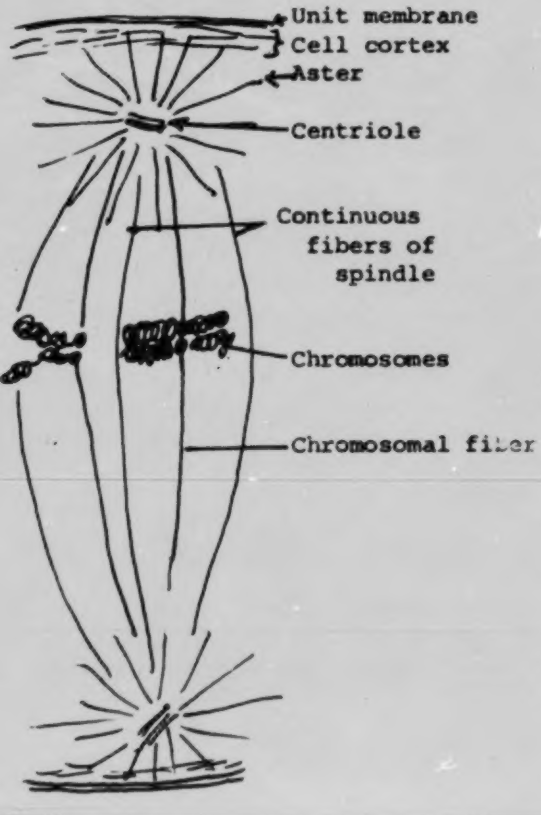

Proteins in tertiary form
Centriole

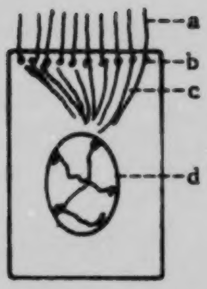

Protein in secondary form

b. Nuclear Sap to Spindl**e Fibers**

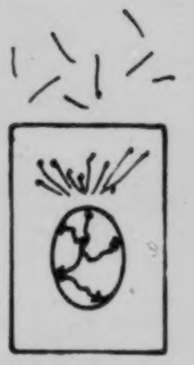
The nuclear sap has some proteins and apparently some are attached to the centromeres of chromosomes. During interphase they are in their **tertiary** form, but with changed environment when the nuclear envelope disrupts they extend.


Proteins in tertiary form
Proteins in secondary form
Centromeres
Chromosomal fibers in tertiary form

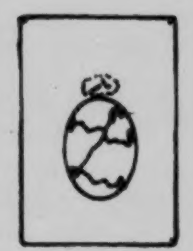

Unit membrane
Cell cortex
Aster
Centriole
Continuous fibers of spindle
Chromosomes
Chromosomal fiber

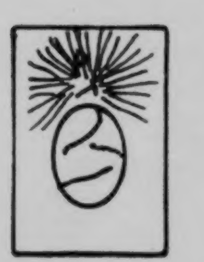


a--cilia
b--asal body
c--ciliary
rootlets
d--nucleus

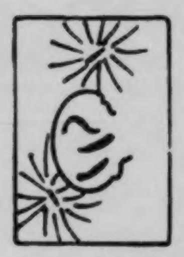


Cilia released and basal bodies migrate to centrosome

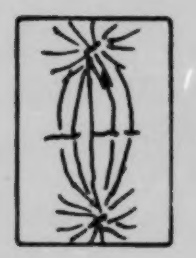


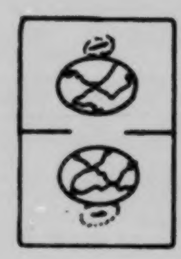


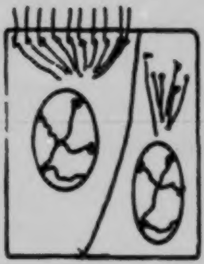
Centrosomal protein unfolds to form aster.



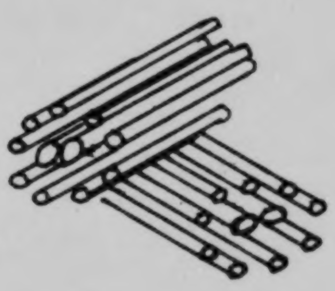
Centriole with astral material migrates to opposite pole.







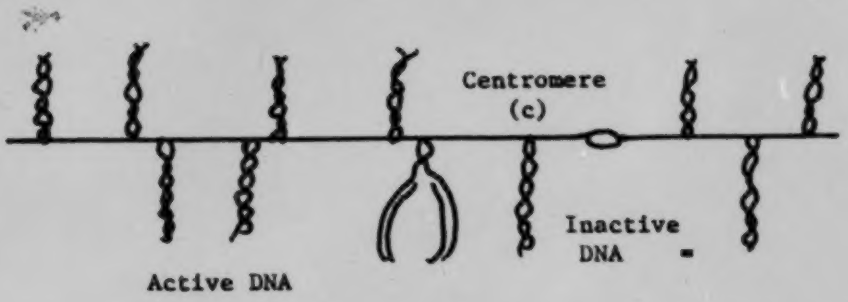
Centrioles break up and migrate to cell surface, then form cilia.

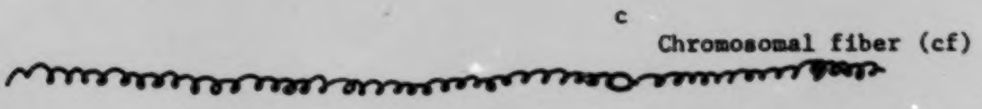


Centriolar pattern as seen by electron microscope. There are 2 central rods and 9 peripheral ones. The two centriolar bundles are oriented at right angles to each other in metabolic cells.

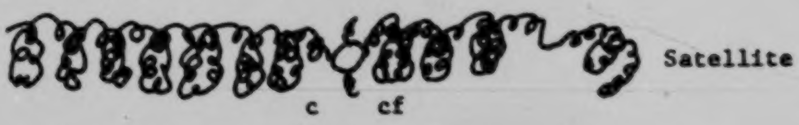
Chromosomes

During Interphase the active chromosome elongates to a macromolecular strand of protein and DNA. Where they are made up of many strands (as in the polytene chromosomes of insect larva salivary glands) puffing represents areas of unravelling and exposure of the genes in that location to the nuclear environment. In the chromosomes of yolky Amphibian eggs, chromosome loops accomplish the same end.

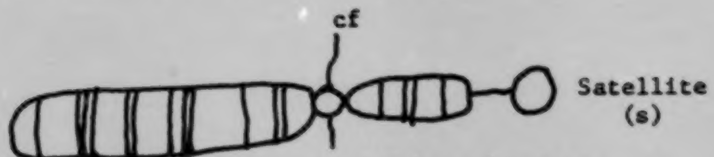

Centromere
(c)
Inactive
DNA
Active DNA


c
Chromosomal fiber (cf)

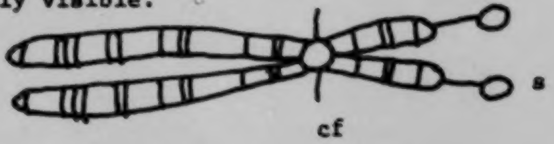
Strand is duplicated then begins to form primary coil.


Satellite
c
cf

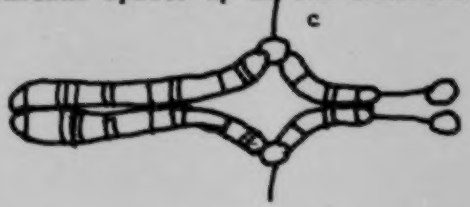
The primary coil becomes coiled into a secondary, larger coil.


cf
Satellite
(s)

The chromosome becomes enclosed in a membrane and characteristic markings become optically visible.



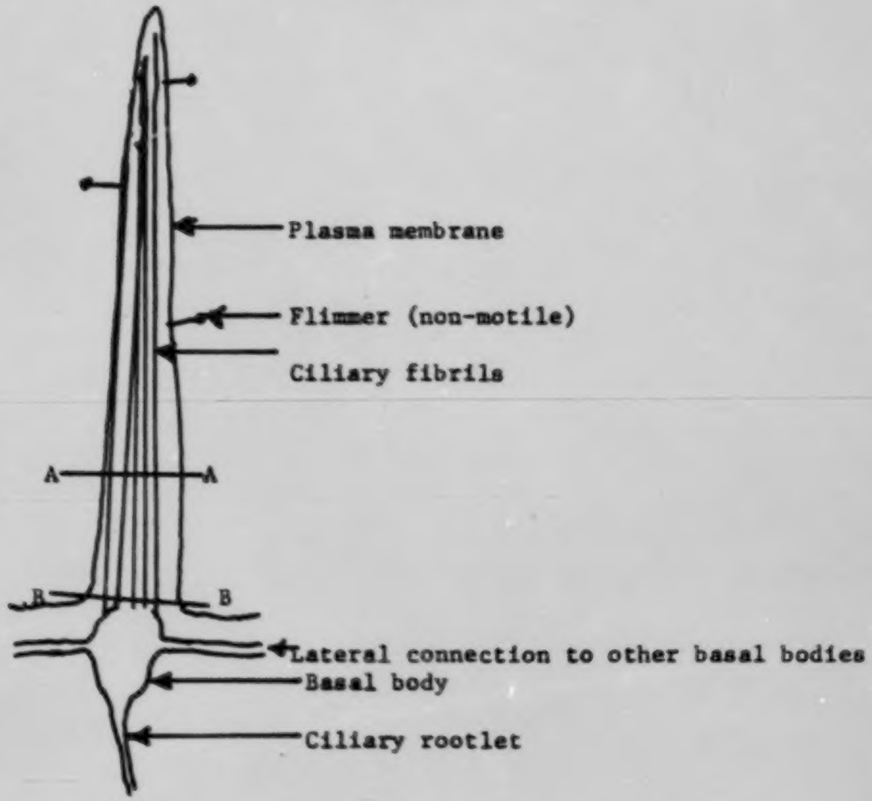
During prophase the chromosome splits up to the centromere.



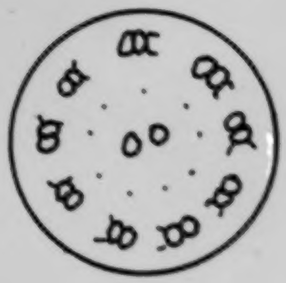
The centromere divides and the halves move apart. The chromosomes appear adherent to each other during this process which occurs in early anaphase.

c. The Centrioles

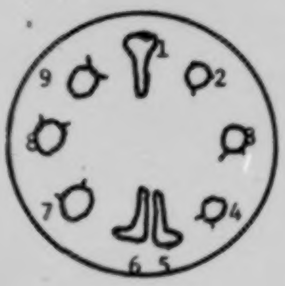
The centrioles consist of two bundles of 9 rods, usually placed at right angles. The nature of this structure is not known, but it has certain qualities attractive to astral and spindle porteins, and therefore, has been known also as the cell center. It functions in cell division to organize the new cells but has quite different functions as the motor apparatus for cilia and flagella.


Plasma membrane
Flimmer (non-motile)
Ciliary fibrils
A
A
B
B
Lateral connection to other basal bodies
Basal body
Ciliary rootlet

A cilium as diagrammed from the electron microscope level of observation. Cross sections at A--A and B--B are shown below.



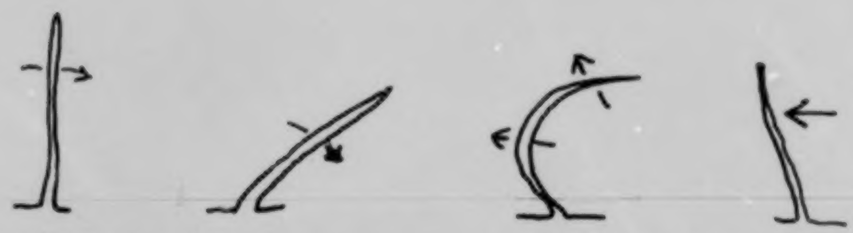
A--A. 9n + 2 fibrils



B--B. Fibrils near the basal body are single. See text for mode of operation.

When ciliated cells get ready to divide they loose their cilia and the basal bodies migrate down the ciliary rootlets and reconstitute the centrioles within the centrosome. They then separate, one centriole carrying some astral portein as it migrates to the basal end of the cell. When division is complete and the astral rays folded, the centriole breaks up and migrates to the free surface where it extends the ciliary or flagella's fibrils (they are the same morphologically), pushing out the plasma membrane. Flimmers are sometimes seen on cilia.

The ciliary fibrils have been shown by antibody-antigen reactions and electron microscopy to be very similar to the actin and myosin of muscle.



Effective stroke

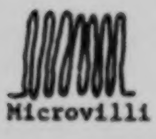
Recovery stroke

Fig. The big fibers (5 and 6) are contracted for the effective stroke, during which the impulse is transfered through fibrils 7,8, and 9. Fiber 1 is contracted at the end of this delay, and during the weaker recovery stroke the impulse passes through fibrils 2, 3, and 4 in time for 5 and 6 to contract for the effective stroke again.

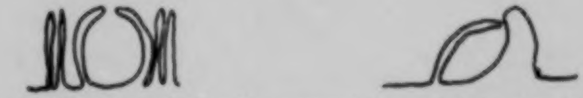
d. The Cell Cortex and Its Modifications

Taking our cue from cilia and flagella, we may assume that it is the cell cortex pushing on the plasma membrane that forms cell interlocks and microvilli.

1) Microvilli occur wherever free surfaces are in contact with water. It increases the surface area a great deal.



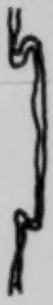
Microvilli



Microvilli forming pinocytotic vesicles by different ways.

Sometimes microvilli will fuse to trap fluids and start an "external" pinocytosis (see above). These microvilli contain an inconstant number of microfibrils or microtubules.

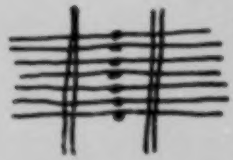
2) Lateral interlocks are sometimes seen on animal tissue cells.



Interlocking lateral microvillus

There is normally about 100Å separation between cell membranes.

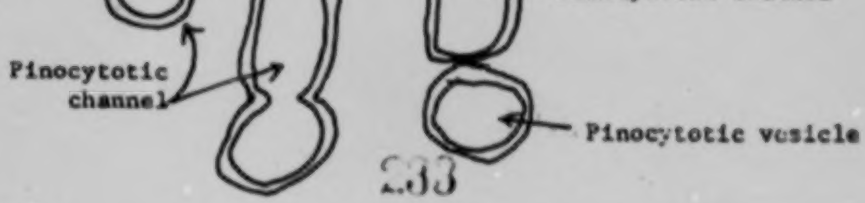
3) Desmosomes (Bridge-bodies)



Microtubules extend into the cytoplasm and bridge the space normally between cells.

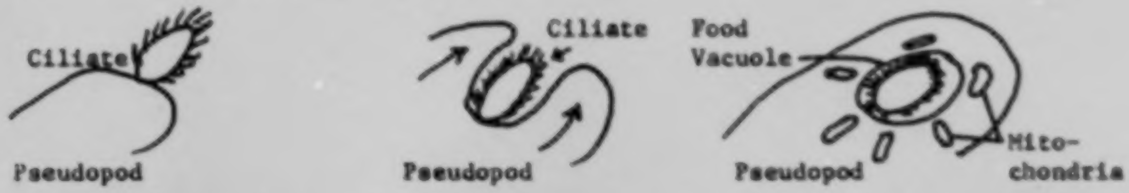
These structures are comprised of some fine tubules that cross the separation that always exists between cells. They serve to bind cells together and to provide a passage for small molecules or messages between cells.

4) Pinocytosis (Cell drinking)



The method of membrane invagination is not understood. This provides a way of brining the outside into the cell area. The vesicle formed is like a vacuole in structure. Active transport is needed to extract the contents.

5) Phagocytosis (Cell eating)



The mechanism of amoeboid movement is operating. See Teacher's Guide to Exercise 10.

5. Protective Coverings

The external part of the unit membrane (as indeed all of it is) is very thin (75Å) and delicate. Yet it is vital, for without it the cell would be a pre-cell again, unable to detect changes in its environment and unable to adapt.

a. Cell Wall

The cell wall is usual for bacteria, non-motile algae, and for fungi and higher plant cells. Cellulose cemented with protein (some with enzyme activity) are the major components. This is laid down in strands, that is, ATP-glucose and cellulose synthase is secreted by the cell and the cell wall is synthesized around the cell. Higher woody plants also make lignin and secrete other products (resins, etc.) into the wood.

b. The one-celled Protista have coverings of chitin. This covering is flexible and is called a lorica. Chitin is synthesized from glucose amine. The Arthropods are the other animal group that makes use of chitin.

c. Intercellular Cement.

Animals are more motile and flexible than woody plants (obvious), but their cell membranes are no more tough or durable than plant cell membranes. The intracellular cement is made from glucose that has first been converted to ascorbic acid (vitamin C). This is hyaluronic acid (Vitamin C was first called uronic acid).

Gums and pectins perform this same functions in fruits, both being derived from glucose.

6. Inclusions

The non-living foods and pigments stored in cells constitute the inclusions. Glycogen, starch, fat droplets, protein crystals, pigment granules (melanin) account for most inclusions. These are not in vacuoles but stored directly in the cytoplasm in animal cells.

7. Cell Division

a. Mitosis

The chromosome material is replicated during interphase. During mitosis (thread formation) in most cells the chromosomes coil up so that they are shorter and thicker and thus become visible in the light microscope. The chromosomes split and are distributed to the resultant cells in sets like those of the parent (usually double). Viruses and bacteria have circular (ring) chromosomes that do not coil up.

The nuclear movements are called karyokinesis (Gr.; Karyo-nuclear; kinesis-movement). The streaming of the cytoplasm concentrates mitochondria and ribosomes around the aster by a process, much-studied but little understood. This is called cytokinesis (more literally cytoplasmic kinesis). The process results in cleavage furrow formation (also not understood). (See Teacher's Guide to Exercise 16).

b. Meiosis (Reduction)

In bisexual reproduction the usual diploid number of chromosomes is reduced to a single set so that a set from both the male and female will participate in zygote formation.

In meiosis two divisions are involved, only the first one of which uses replicated chromosomes.

Meiosis is a form of cell division in which:

The chromosomes are replicated before the first division.

The homologous pairs of chromosomes synapse, bringing gene alleles next to each other.

The chromosome pairs split, forming tetrads (4s) in which condition crossing-over may take place between strands.

The cells then divide, with two sets of chromosomes going to each resultant cell.

The telophase of division I becomes the prophase of division II (without chromosome replication).

In the second division, a single set of chromosomes is transferred to each of the four final cells.

In males four viable spermatid cells are produced. These undergo cell rearrangement (metamorphosis) to form spermatozoa. In females, during the first division a polar body cell and a secondary oöcyte are formed. In the second division the secondary oöcyte divides to form a second polar body cell and a viable egg. Only one viable egg is formed from each primary oöcyte.

c. Fission and Amitosis

Most cells form chromosomes which are visible in the light microscope. Before the perfection of electron microscopy for use in biological study there were some cells in which chromosomes could not be discerned in the light microscope. Yet these cells divided and faithfully transmitted traits just as did cells in which thickened chromosomes could be seen. The terms "fission" and "amitosis" were applied to division in these cells (bacteria, some protozoa, etc.) in those days. Now the electron microscope reveals that these cells (and the viruses, too) form chromosomes which replicate, mutate, and split, just as do chromosomes visible in the light microscope. There are no visible spindles, but that does not conflict with the definition of mitosis (Gr.: thread formation) no more than the lack of a nuclear envelope keep bacteria from being cells.

How can "meiosis" (reduction) occur in cells that are ordinarily haploid? When haploid bacteria mate, the "male" chromosome enters the "female" cell to form a diploid zygote. In this condition mutant gene markers reveal that crossing-over (that is, synapsis of chromosomes) occurs and then at cell division the number of chromosomes is reduced from two to one (reduction or meiosis). Again, a spindle is not essential to the definition. The presence of an attraction center in the form of a centriole is borne out by the fact that cilia and flagella in bacterial cells do have a basal body homologous with basal bodies on such structures in visibly centriolated cells.

Approach 1

The concept of the cell being the basic structural and functional unit of organisms must be stressed to the students.

Show the films: "The Cell", "Cells and Their Functions", or "Protozoa; One-celled Animals."

Ask students to interpret what they saw in the films. It should be emphasized that every structure of the cell seen in the film cannot be seen either with the naked eye or even with a compound microscope. Some of the structures are so minute that they cannot be resolved with the help of a light microscope. The electron microscope is needed in order to resolve these ultrastructures of the cell. The students may then be asked to correlate the functions of the various structures found in a cell. An idea of the division of labor may be given to the student at this stage to show how various organelles become specialized to carry out the various metabolic processes.

The student may be exposed to the diagrams of the cell as given in a Turtox chart or any other good illustration. A model of the cell may also be used to study the cell structures. The student may then be asked to do Exercise 10, in the manual-- Typical Cells. Emphasis should be placed once again upon the fact that all the structures seen in the diagrams and films cannot be seen under the light microscope, since the student may like to see mitochondria, lysosomes, centromeres, etc. A variety of materials may be shown to the student. Details of the cell study have been given in the laboratory manual.

At the next class session, there will be a discussion of drawings and observations of slides. Hopefully, the idea of division of labor and cell specialization for special functions will be developed.

Approach 2

The topic of mitosis can be started with a short film loop ("Mitosis," Ealing Film Loop, EFL). After showing the loop once, ask the students to interpret everything that they saw (list different observations on the board). As the discussion proceeds incorrect observations should be eliminated and correct ones pursued in discussion. Some of the nuclear structures involved in mitosis (centrioles, spindles, chromosomes, etc.) as well as the different phases of the process will have been observed and discussed by this time.

Towards the end of the discussion period several provocative questions should be raised for the students to ponder at home (write on board):

1. Does mitosis occur in all living organisms?
2. What is the sequence of events in the process?
3. Is the process the same in plants and animals?
4. Does understanding the process help us better understand living things? If so, how?
5. Is the mitotic rate the same in all organisms (bacteria, man)?

At this point assign the reading of Laboratory Exercise 16A and B --Cell Division (Mitosis) in preparation for doing it at the next laboratory period.

After students have had an opportunity to observe the different stages of mitosis in both plant and animal preparations, the question "Is there some sequence in mitosis?" should be raised and dealt with. The various phases are then put in the proper sequence and the events that characterize each discussed. The film "Mitosis" (EBF) or "Cell Division, the Basis of Growth for All Living Things" (United World) could be shown to clarify the sequence in mitosis. A model (Turtox JM-32-) or a chart (Turtox T90, Mitosis) could be used in lieu of a film to review the mitotic sequence. At the end of the period an assignment can be made or some questions for discussion or written reports could be listed on the board.

Discussion Questions

1. What evidence exists that structures found in cells confirm the idea that form and function are related?
2. What evidence do cells provide for a common origin of all living things. Support this statement from our knowledge of cell structures and functions.
3. Give several reasons why the cell is considered a fundamental unit in biology.
4. What are some of the fundamental particles in the other sciences?
5. Have additions to our knowledge about cells depended on improvements in tools and technology? Is this true of other sciences?

6. List the parts of cells which contain membranes and the parts which do not. Which is the longer list? Assign a function to each of the parts you listed.

7. Does the membranous structure of a cell part have any relation to the functioning of that part? Explain with examples.

8. In what ways does the form and structure of the nucleus reflect its function?

9. Why does the nucleus seldom show any morphological specialization?

Answers to Discussion Questions

1. The function of membranes is in part to separate the various activities going on in the cell. It is, therefore, thin and semi-permeable.

The nuclear envelope has pores to permit RNAs to migrate to the cytoplasm. The endoplasmic reticulum forms a network through the cytoplasm because its function is to keep a modified "outside" close to all parts of the cytoplasm and to the nucleus. Etc.

2. Cells are all made of protoplasm, more-or-less enclosed by a membrane, and contain nuclear material. Structures such as viruses, mammalian platelets and red blood corpuscles, therefore, are not cells.

This common description is also supported by the fact that all cells begin their energy metabolism with anaerobic glycolysis, use the same mechanism for genetics, divide in the same mysterious ways, and are killed by common factors.

3. The cell is the basic unit in biology because only whoe cells are alive. Large organisms are alive only in their cells. However, the whole organism behaves differently than its constituent parts.

4. Chemistry: electrons, protons, atoms, molecules
Physics: ergs, joules, calories, photons, moments, measures of time and distance

5. Yes. Yes. But mostly it has depended on the philosophical readiness of the scientist to perceive a discovery.

6. Cell and nuclear membranes--control of materials passing through.
Endoplasmic reticulum--synthesis and transport of materials.
Mitochondria--energy production.
Lysosomes--intracellular digestion.
Golgi bodies--secretion.
Chloroplast--photosynthesis.
Vacuoles--support, water regulation, food storage.
Ribosomes--protein synthesis.
Centrioles--organization of the cell.
Nucleoli--ribosomes.
Nuclear sap--formation of spindle fibers
Chromosomes--carriers of genes.
Centrosome--formation of the aster.

7. Yes. Membranes separate the various chemical activities going on in the cell. Where absorption or water excretion is an important activity, membrane folds increases the surface area.

8. As a chemical control center it is usually spherical or disc like. Possibly this is the best form for its function.

9. The nucleus is in direct contact with the environment in which the cell lives. Its form will change with pressures on the cell and the functional state of the cell. White blood cell nuclei are quite variable in shape.

Self Test on Cells:

1. Why has so much significant biological knowledge accrued from studying cells?
   a. Biologists have been studying them for hundreds of years.
   b. Many cells are large enough to be studied with simple magnifying devices.
   c. Most biologists were cytologists until recently.
   d. Cells are basic structural and functional units in living things.

2. The most basic tool for studying cells is the
   a. oscilloscope.
   b. microscope.
   c. centrifuge.
   d. camera.

3. To what does the term ultrastructure refer in Biology?
   a. The molecular structure of biological materials.
   b. Use of the electron microscope.
   c. Large biological structures.
   d. The structures of the nucleus of a cell.

4. Cell membranes, according to recent evidence, consist of
   a. cellulose sheets.
   b. layers of lipid and protein molecules.
   c. a thin strong sheet of protein.
   d. carbohydrate and lipid molecules.

5. Cell membranes are vitally important to cells because
   a. they synthesize food for cells.
   b. proteins are synthesized in them.
   c. they give cells their characteristic shape.
   d. all materials enter and leave through them.

6. Protein synthesis is localized in which of these cell structures?
   a. Ribosomes.
   b. Mitochondria.
   c. Lysosomes.
   d. Golgi bodies.

7. Which of the following functions is performed by mitochondria?
   a. Protein synthesis.
   b. Energy release and storage.
   c. Lipid storage.
   d. All of these.

8. Golgi bodies are especially prominent in cells that
   a. are dividing rapidly.
   b. are active in secretion.
   c. have high energy requirements.
   d. produce digestive enzymes.

9. Grana are membranous structures where
   a. enzymes are synthesized.
   b. lipids are stored.
   c. energy is released.
   d. chlorophyll is concentrated.

10. Vacuoles may function in
   a. food storage.
   b. water elimination.
   c. cell support.
   d. all of these.

11. The threadlike material observed in the nuclei of non-dividing cells represents
   a. uncoiled chromosomes.
   b. endoplasmic reticulum.
   c. ribosomes.
   d. centrioles.
   e. coagulated nucleic acid.

12. During cell division complex events occur
   a. in the nucleus.
   b. in the cytoplasm.
   c. in the cell membrane.

13. Which of the following structures has the least to do with cell division?
   a. Chromosomes.
   b. Spindles.
   c. Ribosomes.

14. If a cell originally has four pairs of chromosomes and divides, how many pairs will each resultant cell have?
   a. 4
   b. 8
   c. 2

15. You would expect to see the following in a stained onion root tip cell in metaphase:
   a. chromosomes in a random or helter-skelter arrangement.
   b. chromosomes, spindle and cell plate.
   c. spindle and chromosomes arranged in a line between the poles.

16. Chromosomes are least visible during which phase of mitosis?
    a. Metaphase.
    b. Interphase.
    c. Prophase.

17. Which structure does not occur in higher plant mitosis?
    a. Cell plate.
    b. Spindles.
    c. Centrioles.

18. Which structure does not occur in animal mitosis?
    a. Centrioles.
    b. Cell plate.
    c. Spindles.

19. Which mitotic sequence is in order?
    a. Interphase, prophase, metaphase, telophase, anaphase.
    b. Interphase, prophase, telophase, metaphase, anaphase.
    c. Interphase, prophase, metaphase, anaphase, telophase.

20. Which of the following added least to the knowledge of mitosis?
    a. Electron microscope.
    b. Light microscope.
    c. Staining techniques.

21. Which of the following men probably contributed most to working out the details of mitosis?
    a. Alexander Fleming.
    b. Walter Flemming.
    c. Theodor Schwann.

21. Which of the following statements are not true?
    a. Mitosis occurs in all living cells.
    b. Mitosis is an orderly sequence of events.
    c. Mitosis results in two daughter cells, each with one half of the mother cell's chromosomes.

22. The spindle fibers appear to be most nearly involved with
    a. pulling the chromosomes into the daughter cells.
    b. forming the cell plate.
    c. causing the chromosomes to thicken during early prophase.

23. The centromere is
    a. fibers associated with the centriole.
    b. located near the poles of the cell.
    c. the place of attachment of the chromosomal spindle fibers.

24. The causes of cell division are
    a. not known.
    b. quite well established and supported by experimental evidence.
    c. can never be really determined.

25. Where would you expect to see the most active cell division?
    a. Cells in the branch of a tree.
    b. Cells in your arm.
    c. Cells in the root tip of a bean plant.

Answers

1. d
2. b
3. a
4. b
5. d
6. a
7. b
8. b
9. d
10. d
11. e
12. a
13. c
14. a
15. c
16. b
17. b
18. c
19. a
20. b
21. c
22. a
23. c
24. a
25. c

A Classroom Account by Mrs. Elizabeth D. Clark, North Carolina A & T State University, Greensboro

MITOSIS

I usually have a problem of providing enough stained onion root tips for an unlimited number of squashes by each student. This quarter I bought some onion bulbs from the plant nursery. I placed twelve of them in an aquarium (12 by 7 in.) on brown paper towels in water. I examined for the roots on the root section of each bulb before placing it in water (Sat., Oct. 17, 1970). On Monday, October 19, the roots were one or more centimeters long. I cut, fixed and stained the root tips and had enough for the classes totaling 138 students to have plenty of material to work with (see Exercise 16).

The students had studied the DNA Replication, RNA and Protein Synthesis in the Unit on the cell. To introduce mitosis, I showed a film on "DNA--Structure and Importance." The film introduced mitosis, meiosis and DNA controlling such traits as albinism, color and sickle cell anemia. The students were asked to study mitosis for lab the next day.

During the lab period the students were given experiment sheets on making squash smears. The students made beautiful squash smears. The chromosomes were not stained deeper than the walls but the cytoplasm was not stained so the position of the chromosomes was clear. I set up a few prepared slides on mitosis in the root tips so that all students could see all of the phases of the process. Some students did not find the chromosomes in the center, migrating to opposite poles, or at the opposite poles, in their squash smears, but they were able to place the stages they found before or after these positions. I checked with the teachers in the other three lab sections of our class. They said that the students had not found mitotic figures so they gave each student a prepared slide. I discussed in each section what we had found, so many students examined their squash smears again and finally found a few mitotic figures.

After the class I took the materials to my office and made two squash smears. I found all stages and set them up for study. I invited the other teachers to come and see them. They found other stages not pointed out. One teacher said that they found some after I left the room. Another asked if it were wise to have experiments where students spent a lot of time looking before they actually found a specimen. I became terribly concerned so I asked the students (next day) to evaluate the experiment in view of the fact that they found so few mitotic figures. The following ideas were advanced:

The scientist does a lot of searching before forming conclusions.

The technicians probably made many smears before they found the ones they sold to the schools.

The prepared sections probably cut through cells and showed fragments whereas their specimens were whole.

Some students said that they enjoyed following through the process and finding the clean, clear mono-layer spreads. They noticed the difference in the size, shapes and structure of cells. They noticed that only the cuboidal cells showed mitotic structures and asked why.

Some students made squash smears of the older parts of root tips and many xylem elements were visible. They made drawings. We returned to these drawings when we made squash smears of dormant wood cells. This made it easier to explain how young undifferentiated cells change into different types of cells according to their final location and function.

The real appreciation came in viewing the time lapse film of the actual movement of chromosomes and other organelles in a cell during mitosis in the onion root tip. It was great. There were no sounds----just the changes of one cell and then another. Occasionally, two cells were going through mitosis at the same time. Finally, a student said, "Now I see why we found only a few mitotic figures in a single squash smear, or how you may not find any if the root tip is killed at a particular time." Another said, "As the chromatids move toward the opposite pole they do appear thicker. I also see what you mean by synapsis and how crossing over could easily occur. Some chromosomes traveled around or over others to go to a pole. I guess that this is why in meiosis, we cannot control the assortment or segretation of genes to a particular sex cell."

When we cut our hands or hurt something, this process accounts for new cell formation and healing of wounds. After making the squash smears and seeing this film loop -- I have a different feeling, respect and understanding of the process and its importance.

One student asked why some chromosomes line up in a transverse plane and in the text the chromosomes line up in a perpendicular plane. We discussed the movement of centrioles in animal cells and the absence of these in plant cells. Another asked if there were centrioles outside in the cytoplasm controlling the movement of these chromosomes. At this point the students were answering each others' questions; e.g.,

Q: If a parent with six chromosomes gives rise to a resultant cell, will the parent remain with three chromosomes?

A: Two resultant cells are formed--both having 6 chromosomes. The parent is half in each resultant cell.

Q: Do cells always divide normally or do mistakes occur?

This introduced polyploidy as a result of mistakes, exposure to colchicine, other chemicals or radiation. I was glad that factors affecting mitosis were introduced here because hormones could be introduced again. (We started the hormone treated chick study the following week. We recalled the ideas that hormones can effect gene activity. In some instances, hormones could effect the intracellular enzyme system, the cell membrane permeability, and effect gene activity. In some instances, hormones could effect the rate of protein synthesis, the rate of mitosis and the pattern of differentiation of cells. In the discussion of the chick project, the students tried to explain their observations with these ideas in mind.

The teachers in the regular program liked this experiment and it is one of those selected to be done in all of the Biological Science classes.

III. Discovery of the Cell

Reference: Hooke (1665) Micrographia. Dover Publications.

Approach:

Present the class with a beaker of water. Drop in a rubber stopper and a cork stopper of the same size and shape. Ask why does one floats and the other one doesn't.

(The rubber is more dense so that it displaces an equal mass of water which is enough to sink it (Archimedes Principle).)

That is the question Robert Hooke asked himself. He then had a microscope built so he could look at the structure. He also looked at a great many other things. His drawing are excellent (worth an A in this course), so we know that Hooke was a careful and thorough observer. Take a look through his Micrographia which is available in the Dover paperback edition in the reading center.

The Janssen brothers had invented a crude compound microscope in 1590 and they must have seen something, perhaps imperfections in gems. However, they were not scientists so they did not report seeing anything else. Seventy-five years later Hooke studied many non-moving biological and non-biological objects using a compound microscope. At the time he was 28 to 30 years old. He wasn't looking for cells. He wanted to find out what made feathers, pumice stone and cork float. Later he looked at living plant material, and as keen an observer as he was, he didn't know what to look for in his boxes or cells, so he didn't discover much in the way of "insides".

Marcello Malpighi and Nehemiah Grew were both embryologists. When they looked at the tissue they expected to find some answers to the question, "Why do things grow?" and "what makes things alive?" They, therefore, discovered what today we call a cell. No details, just the clear jelly-like jewel containing the miraculous state called life! What did they call it? (the utricle.)

Later, Antonie van Leeuwenhoek, a poor boy who studied enough to become the courthouse janitor and tester of barrels used for storing oil, wine, etc. He used a magnifying glass to look at cloth, and later he married the sister of a physician so he started looking at various natural and artificial cultures of microbes. He thus became the first to see free-living cells and to describe them. He also saw other things; blood cells, rotifers, spermatozoa, etc.

IV. Development of the Cell Theory

Specific Reading:
Goolsby (1970). Chap. 4
Kimball, Cell Biology. pp. 52-53

Jean Lamarck (1809-1810) said that all living things, plant or animal, were cellular or of cellular products. He gets credit even though Mirbel had said in 1809 that all plants are made of cells.

In 1838 Mathias Schleiden got into some arguments about plants being made of cells and the next year, 1839, Theodore Schwann made the same assertions for animals. Both, of course, were arguing for Lamarck's point of view. It is doubtful that they ever met. But, they are remembered together for popularizing Lamarck's cell theory.

In 1857 Rudolph Virchow deduced from slides of tumors that cells came from preceeding cells.

The implications of the cell theory are:

1. Life exists only in whole cells.

2. All cells come from pre-existing cells (back to the pre-cell).

Therefore, all living things have evolved from the first living cell or cells.

Discussion Questions on Cell Theories

1. Why was the development of the cell theory spread over almost two hundred years (1678 to 1810)?

2. Contrast the meaning of the term "cell" in the time of Robert Hooke, of Schleiden and Schwann, and at present.

3. State the basic tenets of the cell theory. Is it likely that this theory will change radically in the future? Why?

4. List four major contributors to the cell theory and give their major contributions.

Answers

1. Men were not philosophically oriented to make discoveries about the cell.

2. Hooke's reference to the cell was only in terms of an empty space enclosed by the cell wall; Schleiden and Schwann included cellular content (protoplasm) on a microscopic level; presently, we are aware of microscopic as well as ultrastructures and many of the chemical activities associated with protoplasm.

3. All living things are composed of cells and cell products and the activity of an organism is the result of the activities of its constituent cells. Cells develop from pre-existing cells. Not likely to radically change because it has been verified repeatedly and it is not contradicted by other known biological processes or activities.

4. Jean Lamarck first announced the cell theory; Schleiden, argued the cellular nature of plants; Schwann, argued the cellular nature of animals; Virchow said cells arise from pre-existing cells.

Self Test

1. When Robert Hooke, in 1665, observed think layers of cork with a lens and described his finding as "cells," he was actually seeing
   a. cytoplasm.
   b. cell walls.
   c. living cells.
   d. cell membranes.

2. Anthony van Leeuwenhoek stimulated the development of biology through which of the following discoveries?
   a. Cells.
   b. Mitosis.
   c. Microscope.
   d. Blood circulation.

3. The statement, "The cell is the basic unit of structure, function, and reproduction of living matter," represents the
   a. organismal concept.
   b. definition of a cell.
   c. species concept.
   d. cell principle.

4. In 1838, Schwann, on the basis of his own observations as well as the observations of others, advanced the tentative conclusion that all living things are composed of cells. This statement, when first made in 1838, was
   a. an assumption.
   b. an observation.
   c. a generalization.
   d. a law.

5. "All cells come from pre-existing cells," was first stated by
   a. Hooke.
   b. Schwann.
   c. Virchow.
   d. Schleiden.

Answers

1. b
2. c
3. d
4. c
5. c

Review Questions on The Cell

1. The cell has been defined as "the basic structural and functional unit of life." What is your interpretation of this statement?

2. Why is it important that we study the cell and how it functions?

3. Do persons majoring in home economic, political science, sociology and other "non-biological" areas really have a need for studying the structure and activities of cells? What benefits might they gain?

4. In what ways does the analogy between the cells of our body and the bricks of a house fail?

5. Suppose you were given a piece of fresh tissue, the cells of which you were asked to study. What instruments and techniques would you be required to be familiar with in order to study the cells and some of their components?

6. Many times we draw an analogy between a gelatinous mass, such as jello, and protoplasm. In what respects is this analogy a poor one? a good one?

7. List as many structures associated with the "typical" cell as you can and where possible, describe briefly what would happen if something were to inactivate each of the structures listed.

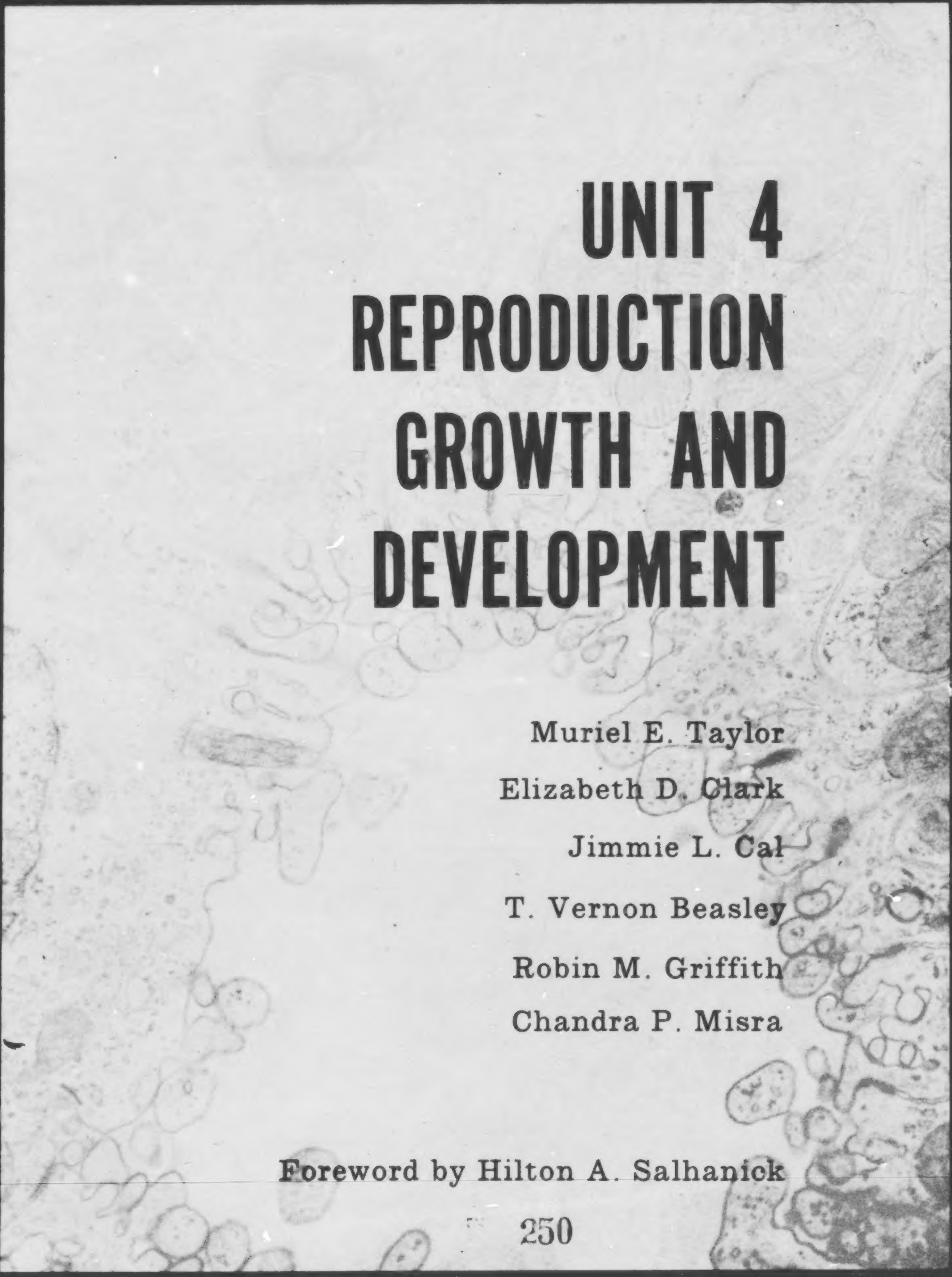
8. What are some of the advantages to an organism having its body organized multicellularly rather than being a single massive piece of protoplasm?

9. Of what importance to living things is the phenomena of diffusion? osmosis? active transport?

10. What are organic molecules? If your cells were analyzed thoroughly by qualitative means, what are some of the large organic molecules which might be present?

11. What mechanisms and activities are involved in the process of cell division? What are some of the outcomes of cell division or reasons why cell division is important?

12. What concepts are generally included in our modern day cell theory?



UNIT 4

REPRODUCTION GROWTH AND DEVELOPMENT

Muriel E. Taylor
Elizabeth D. Clark
Jimmie L. Cal
T. Vernon Beasley
Robin M. Griffith
Chandra P. Misra

Foreword by Hilton A. Salhanick

FOREWORD

Reproduction, the criterion by which life is defined, is a magnificently intricate means of maintaining the existence of a species against great odds. Nature has innovated many designs for accomplishing this goal, and the variations in rhythms and processes of the various species deserve study far beyond current meager efforts.

Reproduction, however, is concerned not only with life but also with living. Strong reproductive instincts can be controlled only if they are understood. The problems of unwanted children, venereal disease and family instability are soluble only by comprehension of the roles of reproduction in our daily lives.

This curriculum, therefore, accepts two challenges. First, the beauty of Nature's complexity for preservation of life is reflected in the breadth and variety of the outline. Second, the truth of today's living is emphasized by extensive coverage of the human reproductive system. We believe that both are the essence of modern education.

Hilton A. Salhanick, M.D., Ph. D.
Director, Center for Population Studies
Harvard School of Public Health
Boston, Massachusetts

REPRODUCTION, GROWTH AND DEVELOPMENT

INTRODUCTION

The life functions are reproduction, metabolism, irritability and adaptability. A species must carry out all of these in order to be considered alive. Reproduction is one of these functions, yet it is different, for it is not necessary to keep the individual organism alive. It is one of the most important aspects because it represents the only link between past and future generations. There comes a time when an organism is not able to carry on its life functions. Aging, attack by predators, starvation, parasites and pollutions are a few of the many obstacles that prevent an organism from carrying on the life functions. However, the various species survive only slightly longer than they can reproduce, for survival requires the production of new individuals by living predecessors. The body is mortal, but the germ plasm, passed from generation to generation, has attained a kind of immortality to the present time.

Reproduction irrespective of sex (commonly called by the misnomer "asexual") involves a single parent which gives rise to new offsprings, all of which have heredity material identical to that of the parent because there has been no new genetic material added. All cells have a sex.

In sexual reproduction, male and female gametes, sperm and egg, or equivalent cells, come together at the time of fertilization, and their chromosomes become intermixed for the first zygotic cleavage.

One of the most amazing aspects of biology is how a new organism develops from one cell, a development so precisely controlled that entire intricate organization of cells, tissues, organs, organ systems characterizing the functioning adult comes into being with few flaws. It is the DNA and RNA that controls development and insures that a rat zygote develops into a rat, a chrysanthemum zygote into a chrysanthemum, and a frog zygote into a frog.

The specific objectives sought in teaching this unit are:

1. Understanding why the cell is the necessary preliminary for the reproduction and development of the organism and for the continuity of the living state--all life from life.

2. Developing an awareness of the forms of reproduction irrespective of sex and sexual reproduction.

3. Understanding the significance of sexual reproduction for genetic change which leads to physiologic adaptation.

4. Understanding that human reproduction is secondary to the social activity of sexual intercourse.

5. Understanding the basic functions of the reproductive system of mammals as a protected environment for embryonic and fetal life.

6. Developing an appreciation for the orderliness of embryonic development, each step inducing the following steps.

7. Understanding that mammalian embryos and fetuses are separate organisms from their mothers.

8. Understanding contraception.

9. Understanding life cycles.

PROGRESS INVENTORY

ANSWERS

True-False Statements

1. T
2. F
3. T
4. T
5. T
6. T
7. T
8. F
9. F
10. F

Selection

1. b
2. c
3. d
4. b
5. a
6. b
7. b

Matching

1. F
2. E
3. B
4. C
5. A

REPRODUCTION, GROWTH AND DEVELOPMENT

PROGRESS INVENTORY

True-False Statements

____ 1. Asexual reproduction creates offspring that are virtually identical with the parent organism.

____ 2. Mitosis, budding, regeneration, are asexual methods of reproduction.

____ 3. The amoeba, Paramecium, Spirogyra, yeast, Hydra, bacteria and some higher plants reproduce asexually sometimes.

____ 4. Sexual reproduction results in offspring that are slightly different from either parent.

____ 5. Conjugation and fertilization are sexual methods of reproduction.

____ 6. Sexual reproduction increases the probability of individuals with new characteristics or combinations of characteristics as distinguished from natural mutations.

____ 7. Fertilization in plants in which one sperm unites with the ovum and a second sperm unites with the two endosperm nuclei is called double fertilization.

____ 8. There is no value in the releasing of a large number of sperm in mammals in which only one egg is fertilized.

____ 9. The external environment (temperature, pH gradient, light, etc.) does not significantly affect growth and development of man.

____ 10. The development of new individuals from unfertilized eggs is known as gametogenesis.

SELECTION

____ 1. The male sex hormone, testosterone, is secreted by the
a) ductus deferens
b) interstitial cells of leydig
c) anterior hypophysis
d) sperm
e) none of these

____ 2. The most important hormone in initiating and maintaining lactation is:
a) oxytocin
b) estrogen
c) prolactin
d) progesterone
e) all of these

____ 3. The ovarian trophic hormone (s) elaborated by the anterior hypophysis is (are):

a) ICSH
b) LTH
c) FSH
d) LH
e) all of these

____ 4. The menstrual cycle can be divided into three continuous phases. Starting from the first day of the cycle, their consecutive order is:

a) secretory, menstrual, proliferative
b) menstrual, proliferative, secretory
c) proliferative, menstrual, secretory
d) menstrual, secretory, proliferative
e) none of these

____ 5. The ovum is normally fertilized:

a) 1/3 the way down the uterine tube
b) mid-way the uterine cavity
c) at the end of the uterine cavity
d) in the vagina
e) in the Fallopian tubes

____ 6. The stage at which the fertilized human egg develops into a spherical mass of cells is called:

a) zygote
b) morula
c) gastrula
d) blastula
e) none of these

____ 7. The fetal membrane (s) of the placenta consist (s) of:

a) chorion
b) amnion
c) allantois
d) all of these
e) none of these

MATCHING

____ 1. A cell containing little cytoplasm, produced in meiosis during the production of female gametes.

____ 2. A single chromosome of a chromosome pair.

____ 3. The diploid generation of a flowering plant.

____ 4. The stage of mitosis in which chromosomes replicate.

____ 5. A form of bacterial cell that survives in the absence of water.

A) spore
B) sporophyte
C) interphase
D) endosperm
E) homologue
F) polar body

REPRODUCTION, GROWTH AND DEVELOPMENT

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Girl to Woman. Mass. Dept. of Public Health.

REPRODUCTION, GROWTH AND DEVELOPMENT

TOPIC OUTLINE

I. A Preliminary Exploration of Sex and Reproduction

   A. Attributes of Reproduction

   B. Attributes of Sex

II. Reproduction Without Respect to Sex

   A. Mitosis As A Reproductive Process
      1. Budding
      2. Fragmentation

   B. How New Information Is Changing Older Ideas About Mitosis
      1. Fission--a form of mitosis

   C. Processes Associated With Survival But Which Are Not Reproductive Processes
      1. Sporulation
      2. Regeneration in Animals and Plants
         a. Autotomy
         b. Generation of carrot from a few somatic cells
         c. Grafts and other transplants

III. Sexual Reproduction

   A. Anatomy and Histology of the Mammalian Reproductive System (With Emphasis on Man)
      1. Male System
      2. Female System

   B. Gametogenesis
      1. Male
      2. Female

   C. Factors Affecting Mating and Ovulation
      1. Invertebrates
      2. Vertebrates
         a. Fish
         b. Amphibians vary. Frogs
         c. Reptiles and Birds
         d. Hormonal Relationships in Mammals
            Estrus cycles
            Menstrual cycle
            Contraceptive steroids

- D. Fertilization
  - 1. Non-Copulating Invertebrates
    - a. Termones and gamete attraction
    - b. Fertilization processes
      - 1) Sperm entrance
      - 2) Meiotic Divisions in the egg
      - 3) Formation of the zygotic spindle
  - 2. Copulating Invertebrates
    - a. Paramecium
    - b. Tapeworms
    - c. Earthworms
  - 3. Vertebrate Copulation and Fertilization
    - a. Fish and Amphibians -- external, in the water
    - b. Reptiles and Birds
    - c. Man as an example in Mammals
  - 4. Conception Control
  - 5. Human Placentation

IV. Development and Growth

- A. In Amphioxus
  - 1. Chemodifferentiation, cleavage, blastula, gastrula, epiboly over the dorsal lip of the blastopore, the notochord, somites, neural tube and coelome

- B. In Man
  - 1. Cleavage, blastula, gastrula and membranes of the placenta, germ layers
  - 2. Organs arising from the germ layers
  - 3. Placental Function
  - 4. Parturition
  - 5. Lactation and Nurture

V. Life Cycles

- A. Alternation of Sexual and Asexual Generations

- B. Alternation of Sporophyte and Gametophyte Generations in Flowering Plants

VI. Regulation of Growth and Development

- A. Chemodifferentiation
  - 1. Determination
  - 2. Mosaic and Regulative Eggs

- B. Gradient Fields
  - 1. Adaptive Enzymes
  - 2. Differentiation
  - 3. Evidence from regeneration experiments
    - a. Planaria
    - b. Salamander
    - c. Liver

C. Stimulation of Growth
    1. Nutrition
    2. Loss of nuclear control theory
    3. Hormones
    4. Carcinogens

D. Suppression of Growth
    1. General application
    2. Alkaloid drugs - Colchicine
    3. X-rays and isotope radiation

REPRODUCTION, GROWTH AND DEVELOPMENT

ANNOTATED OUTLINE

I. A Preliminary Exploration of Sex and Reproduction

A. Attributes of Reproduction

The formation of proteins in the ancient seas enabled these macromolecules to extract energy stored in the hydrogens of the substrate foods there. It was important for the further development of this community of molecules toward the living state that proteins that had the capacity to act as enzymes should be preserved and be incorporated in the chain of metabolic reactions. In order to prevent the disappearance of vital members of the chain, it was necessary for them to be reproduced. This reproduction of proteins was accomplished by the series of nucleic acids (with which we are now familiar) with the reproduction of DNA forming the stable genetic substance. The replication of DNA, therefore preserved the amino acid sequences invented by chance in the ancient seas, at least those sequences which could extract energy needed to minimize entropy.

The essence of cellular reproduction, then, is the replication of the DNA material in sets so that all of the proteins needed for a particular species of living organisms can be produced at the proper time for their growth and development.

The DNA became organized with protein into genes, and these materials were linked together into strands which we now consider to be the fundamental materials of chromosomes. The non-living, but organized assembly of nucleic acids and proteins that make up the viruses have chromosomes. The prokaryotic cells, like those of the eubacteria, also organize their DNA-protein into chromosome strands. In the bacteria and viruses these are usually formed in rings, and can only be seen with the aid of an electron microscope. In higher cells than these a nuclear envelope is present (as a rule) and chromosomes visible in the light microscope are formed when the cells are dividing. The transmission of DNA in these structures (chromosomes) continues to be the essence of the process by which the living state is passed from cell to cell and from organism to organism.

B. Attributes of Sex

It is most usual to have two sets of the genetic material. That is a reasonable factor of safety. We usually think of there being two sexes--male and female. However, this may not always be so, some species of Rotifers have gone along for hundreds of generations without anyone ever having seen a male. Some organisms have many sexes, for example the protozoan, Paramecium, has 14 sexes.

Approach

Ask the class what the main differences are between male and female human beings, other mammals, and between male and female trees. Who can tell the difference between male and female guinea pigs? (Male guinea pigs can tell females easily.) List these attributes on the chalkboard. It should develop that in trying to define human sex, that there are anatomical, physiological and psychological differences, which are usually not put into words, that is, they are non-verbal but widely understood.

Take horseshoe magnets and ask a student to place the north pole of one close to the south pole of the other. Can he explain why they are attracted? This is an analogy. We cannot explain why opposite mating types are attracted to each other, but they are. We cannot say that males and females look differently, for frequently they do not (as shown by some of the 1971 fashions which make it difficult to tell men from women). Among the algae this is very common. Isogametes all look alike.

[It would be good to have some charts of the following types of cells to present as these points are brought out.]

Sometimes two cells touch each other and send only a small connecting bridge to the other for the transmission of the genetic material, as in the conjugation of Paramecium, in some algae (Spirogyra), and in bacteria (E.coli).

Sometimes whole cells fuse before their chromosomes intermix. The cells are the same in appearance and so are called isogametes, and this kind of fusion is called isogamy. Many algae form gametes that are similar in structure but different in size--a small, motile "male" fuses with a less motile, larger "female".

This is not unlike the situation in most animals, including man, where there is a larger, immotile egg which is entered by only part of the male cell--Golgi, nucleus, mitochondria, ribosomes and centriole with cytoplasm in the merest trace. Usually the tail is left outside.

There are also "+" and "-" strains of thalli among the molds (especially in the Mucorales).

Paramecium aurelia is known to have 7 pairs of "mating types". These are basically sexes between mating pairs, but not between non-mating pairs.

In all of these cases there is an attraction between two kinds of cells resulting in the transfer of DNA, whether one calls it male and female, "+" and "-", iso- or hetero-gamy, what is being referred to are sexes.

II. Reproduction Without Respect to Sex

Specific Reference
Sussman (1968) Chap. 2 and 4

Alternate References:
Curtis (1968) pp. 175-180, 250-251, 446
Simpson and Beck (1969) pp. 180-182
Cronquist (1961) pp. 489-495
Singer (1958) Offprint #105
Stanier et al. (1963) Ch. 5, 6, and 7

A. Mitosis As A Reproductive Process

Growth may be defined as either an increase in size, or an increase in the number of cells of the same kind, as in the growth of a colony or clone of cells. While there is a low rate of spontaneous mutation going on in colonies of bacteria or protozoa, the organisms that are produced mitotically are the same genetically, for the single cell carries all of the genetic material that it will give, and it is a copy of such material that gets transmitted when the cell divides. It is interesting to note that most of these are haploid (1n) types of cells, but electron micrographs show two strands separating, indicating that the chromosomes are duplicated before cell division, so that just before cell division they are 2n.

1. Budding

Budding may be unicellular or multicellular. Basically unicellular organisms, such as yeasts, divide mitotically, but form cells, the unequal cell being called a bud.

Many animals in the lower Phyla form multicellular bodies by budding. The body cells in a local area begin to divide forming a clump which comes under the influence of what experimental embryologists call a "gradient field", so that as the bud continues to grow, a completely differentiated copy of the parent, perhaps a little smaller in size, is formed and finally detaches.

2. Fragmentation

When the nucleus divides many times and this is followed after several nuclear divisions by cytoplasmic divisions, we have the situation that has been classically described as fragmentation. If each cytoplasmic frament has the necessary components to permit the nuclear material (DNA) to function, then it will conform to a gradient field and produce a complete adult, as in the parasitic wasp, Habrobracon. In mammals, it is common to form thromboplastids in a similar way, except that the nuclear material stays together in the mega-karyocyte, and only the peripheral cytoplasm divides into fragments.

B. How New Information Is Changing Older Ideas About Mitosis

Our position that all cell division is either mitosis or meiosis has several roots.

We assert that all cells have a common ancestor in the pre-cell and the first cell(s). Since metabolism, membrane transport, energy extraction and cell irritability have been "fossilized", as it were, and are operating today, no doubt as they did when they were invented, the methods of cell division must have also existed from the beginning of cellular life.

The investigators who named the process mitosis (thread-formation) perhaps did so by a lucky coincidence. Before the electron microscope (EM) was available, a chromosome was something that you could see in the light microscope. Paradoxically, it is difficult to see the same structure we call a chromosome in the light microscope when we examine cell nuclei with the EM.

One may ask, "Is a spindle necessary in order to have mitosis?" This question might be examined closely, and perhaps we can even ask what is it that the spindle does. The investigations have shown that if the spindle is cut by microdissection, chromosomes still move away from the equator at anaphase, but they move out of the spindle area. That is, the spindle seems to guide them, but it does not seem to move chromosomes. By light microscope it is seen that chromosomes split during prophase and at anaphase the halves move apart to opposite poles. What makes them move? Why don't both strands go to the same pole? We simply do not know what makes the chromosomes move apart, or what makes them move in the direction of the centriole.

Fission is an example of a kind of cell division believed to have existed up to the time of the electron microscope. One can ask, how can an amorphous mass of nuclear material behave in a coordinated way. Even when it is organized into chromosomes it wants to do flip-flops and cross-over a lot. There is no reason to believe that an amorphous glob of nucleic acid would be able to divide itself so that one of each kind of gene would go to each of the resulting cells. Indeed, the fact that chromosomes have been photographed in such unlikely material as a virus (which although almost alive, is not quite so) would be a strong indication that chromosomes must exist in all living and almost-living things.

Another idea that is changing more slowly is the idea of a "daughter" cell. A cell exists. It takes in food and gives off wastes. Some of the food is used to make new proteins and some is used to make new nucleic acids. It's still the same cell. Then it divides in two. The same cell is now in two compartments. They have not been the product of a fertilization. They have been formed without respect to sex, so why not call them resultant cells rather than using somewhat misplaced sentiment in order to call them "daughter" cells.

C. Processes Associated With Survival But Which Are Not Reproductive Processes

1. Sporulation

One feature of spore formation in bacteria and protozoa is that a cell can dehydrate itself without destroying its organization. The result is a particle that is covered by a shell, but one which is permeable to water. It can keep a long time (many years). When water is added under "favorable" conditions, the cellular material in the spore becomes reconstituted to active living protoplasm and emerges from the spore case.

One spore produces one reconstitued cell. There is no multiplication of cells. It was only a preservation, therefore, not reproduction.

2. Regeneration In Animals and Plants

a. Autotomy is the term used to describe a piece of an animal (tome--cut) that has been cut away and is able to establish its gradient field and regenerate and grow to size.

A non-explanation for why we grow just so tall, or have fingers just so long, and no longer, is usually answered by a terse "it's genetic", all of which doesn't explain anything.

In wound-healing, the connective tissue for a scar "knows" to stop when it reaches the body surface, except that where there are slow-healing processes going on in some Blacks, the tissue continues to accumulate until a mounded scar is formed, called a "keloid" scar.

The amount of body needed for autotomy varies. A starfish needs some of the central part. Dugesia (Planaria) needs only a small piece. The marine sponge, Ciona, can be put through silk bolting cloth and left in sea water for two or three weeks at the end of which time it will have reaggregated, but if all the cells are in one dish, there will be only one sponge.

b. If a few cells from a carrot root are cultured on some sterile, nutrient agar, they will grow into a mound of cells called a callus. The callus then gives rise to a leaf, then more leaves, and then a new root, and a whole carrot can be formed vegetatively. If this process could be carried out with people, then some cheek scrapings from a man could be cultured to give rise to an offspring -- a real "chip off the old block".

c. Grafts and other Transplants. (See Exercise 21) Although plant grafts are listed in the manual under artifical asexual reproduction, there is reason to consider this not to be reproduction in the real sense. Like in the division of a protozoan cell, or other non-differentiating cell, the two resulting cells are really a division of the first one, so that there is no new genetic material. Grafting is one way of maintaining life in a piece of a plant but it is still part of the generation that supplied the graft.

Approach for Reproduction without Respect to Sex

Have the class prepare hay infusion cultures for protozoa as indicated in Section I of Unit 8 and perform the observations indicated (see Teacher's Guide to Exercise 42). For this unit the class should be asked to look for any evidences that would indicate that the cells are reproducing or recovering from sporulation, etc.

Then introduce the class discussion period by showing the film, "Microorganisms with Chlorophyll", or a similar film. Using Euglena, Chlamydomonas, and Spirogyra, this film introduces such concepts as adaptation, phototaxis, means of locomotion, formation of starch, as well as methods of reproduction. After the film, if the students do not start the discussion or ask questions, motivate them to make comments by asking the following types of questions:

List the number and types of characteristics of living things you observed in the film (the student introduces the term reproduction).

Did you see any organisms going through reproduction?

Differentiate between those reproducing and those not reproducing (in the same type of individual) with reference to size, shape, structure, rate of movement, and any other behavioral pattern observed.

How many types of reproduction did you observe? Did any one type of organism experience two types of reproduction?

With reference to their rate of movement or means of defense, if any, would these organisms produce large numbers of offsprings or small numbers of offsprings in perpetuating their species?

At the end of this discussion period, give the students copies of the references and ask them to read first the specific student references.

An alternate laboratory activity

Obtain a supply of Dugesia (Planaria). Have each pair of students obtain one (or one each) and study it under the stereoscopic microscope for a few minutes then make a drawing. Then, using a razor blade, have different students cut their flatworms in different ways--some at different horizontal levels, some on the diagonal, some longitudinally through the head, some completely longitudinally just to one side of the midline. Have them leave their worms in individual dishes of pond water labelled with their name, laboratory section, and the date. They should measure the pieces and sketch their shape and development twice weekly until regeneration is completed.

The following film loops may be used:

Mitosis. Ealing Corp.

Budding of Yeast Cells. Educational Services, Inc. 4 min. Shows structural and developmental details of the process.

Chlamydomonas: Reproduction and Life Cycle. Princeton Univ. Films. Depicts asexual reproduction in this unicellular fresh water green alga. 4 min. 20 sec.

Films:

Microorganisms with Chlorophyll. McGraw-Hill Films. Our Living World Series. Includes asexual reproduction of three unicellular green algae: Euglena, Chlamydomonas and Spirogyra. 16 min.

The Bryophytes. McGraw-Hill Films. Our Living World Series. Using mosses as the main example, the film details the asexual and sexual life cycle of the bryophytes. 16 min.

Charts of "Asexual" Reproduction:

Turtox Class-room Charts offer a good selection.

III. Sexual Reproduction

Specific Reading:
Galston (1964)
Corner (1963)

Alternate Reading:
Berthold (1848) in Gabriel and Fogel (1955) pp. 57-60
Curtis (1968) pp. 323-324
Csapo (1958) Scientific American
McGee. (1927)

Ortho (1968) pp. 44-46
Patten (1964) pp. 68-79
Turner (1960) pp. 454-459, 491-493, 527-530
Ray (1963) pp. 114-118

Teacher References:
Arey (1965) Chap. IX
Zarrow et al. (1964)

Turtox Charts:

Spermatogenesis and Oogenesis, Gametes--Typical Ova and Sperms of Animals, Human Reproductive Organs--Male, Human Reproductive Organs--Female, Cleavage--Blastula and Gastrula, Frog--Male and Female Urogenital Systems, Animal Selections--Embryological Stages, and Plant Selections--Life History.

Filmstrip:

Reproduction Among Mammals. Encyclopedia Britannica Filmstrips. The Human Body Series.

Film-Loops:

Frog Development Series. Ealing Film-Loops. 4 min. each loop. This group of film-loops records an excellent record of frog egg fertilization and embryology. Using time-lapse photography, the development of a single from egg is followed continuously over a period of about five days. Frogs: Pairing and Egg Laying; Part 1. First Cell Division to Neural Folds, Part 2. Development of the Body Regions, Part 3. Continued Development to Hatching.

Human Reproduction and Birth. Ealing Film-Loops. 6 Loop Set. These six loops are a frank and direct film on sex education. Yet they are also filled with human compassion. They have been adapted from an internationally acclaimed film made in Sweden by Lennart Nilsson whose photographs of human embryos were published by Life (1965). They follow the course of a pregnancy, depict delivery and care of newborn baby, and portray role of father. The set includes: Menstrual Cycle, Sexual Intercourse, Fertilization and Early Development, Embryo and Fetus, Human Birth, and The Newborn Baby.

Films:

Life of the Angiosperm. McGraw-Hill Films. Our Living World Series. Studies life history of flowering plants, reviewing processes of gametogenesis and fertilization. An interesting experiment examines the role of the stigma, style and ovary and the growth of the pollen tube.

Family Planning. Walt Disney Films. An animated short story in which Donald Duck and a group of other cartoon characters illustrate the problem of overpopulation in terms of a single family. Through family planning, the film argues, man can choose the proper size of his family and thus benefit not only himself but the entire "family of man".

A. Anatomy and Histology of the Mammalian Reproductive System (with emphasis on Man)

Study the Urinary and male and female reproductive tract in the fetal pig--Exercise 19--before beginning this section for discussion.

To begin the classroom discussion, show the film "Amplexus in the Frog", then ask about the location of the fertilized eggs, etc. Has anyone ever tried to hatch frog or salamander eggs in an aquarium where there were fish? (If so, they will know that the fish ate the eggs.) How, then, could the eggs be protected from that kind of loss? (By placing them in an aquarium without any fish, but that is not the situation in nature. The frogs and the fish live in the same water.)

When reptiles and birds came out of the water onto land, they provided food and water for each zygote and formed a shell about it and left them to hatch away from fish (but not other egg-eaters). In the case of the more highly-developed bird, heat was applied and parental care and nurture instituted in order to promote better survival.

Among the lowest orders of mammals, the duckbilled Platypus and the spiny ant-eaters like Echidna and Pangolin, a shelled egg is formed and incubated internally. Finally the urinary system tubes become adapted for the protection of the embryos and fetuses, the discarded Wolffian duct of the mesonephric kidney being converted to uteri and finally into a single uterus.

Use charts or torso model of the human reproductive systems for this discussion.

1. Male Reproductive System includes the testes located in a scrotum (a temperature-regulating device)· Large mammals such as the elephant have internal testes as do infra-mammalian animals). Applied to the testis is the epididymis, and a tube, the ductus deferens, leads into the body cavity

past the seminal vesicles to the prostate gland. Here it joins the urethra coming from the bladder. The urethra extends through the penis, or erectile male organ. In addition to the urethra, it contains two cylinders of spongy tissue which will upon appropriate psychic stimulation become engorged with blood, thereby erecting this organ. Prolonged, painful erection is called a priapism. Withdrawal of the blood and return to the limp condition is called anelepsis.

2. Female Reproductive System consists of the ovaries, the fallopian tubes (oviducts), and the uterus. The uterus is divided into the fundus (basket) and the cervix (neck). The cervix extends into the vagina (sheath) which opens into a vestibule formed by the external genital folds of the vulva. In the top of the inner folds (labia minora) is located the clitoris or undeveloped penis. (In the male, the scrotum is formed from the vaginal rudiment--tunica vaginalis.) Note: The urethral orifice does not open into the vagina.

The full development of these parts (after childhood) depends upon the stimulation of the sex hormones secreted by the gonads and by the adrenal glands. The hormones are somewhat similar, so that an oversupply of androgen from the adrenal gland may cause the enlargement of the clitoris in some females (lesbians). There are only about 35 or 40 cases of true intersexes recorded, that is, individuals having both male and female external genitalia. More frequently the hormones may cause the development of the opposite sex organs than indicated by the XY chromosome constitution. Urologists and gynocologists usually use surgery to restore the external organs appropriate to the genetic sex.

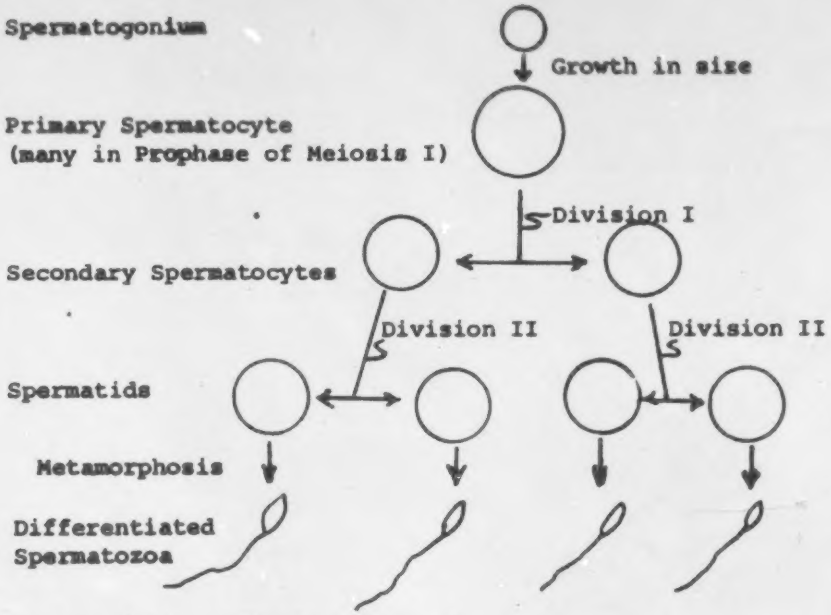
B. Gametogenesis(the production of gametes or reproductive cells)

The primary sex cells are differentiated in the lining of the gut of the early embryo and these migrate through the tissues to the coelomic epithlium over the embryonic kidney (mesonephros) . Here the epithelium pushes down into the connective tissue over the kidney forming cords of epithelium and primary sex cells (Pfluger's cords or ovigerous cords). This indifferent gonad differentiates into an ovary or a testis, with the primary sex cells being responsible for the germplasm and the epithelial cells forming other supporting structures.

1. In the male (with emphasis on man)

The primary sex cell lies dormant until just before puberty (age 12 to 18, mean about 15), at which time they undergo mitosis, somewhat enlarging the size of the testes, and then spermatogenesis begins to occur, that is, the formation of spermatozoa. At this time the primary sex cells become privileged to undergo meiosis by a process undetermined at this time.

Do Exercise 25, Histological Study of the Male Reproductive System, at this time. The following chart summarizes the morphological sequence.


Spermatogonium
Growth in size
Primary Spermatocyte
(many in Prophase of Meiosis I)
Division I
Secondary Spermatocytes
Division II
Division II
Spermatids
Metamorphosis
Differentiated
Spermatozoa

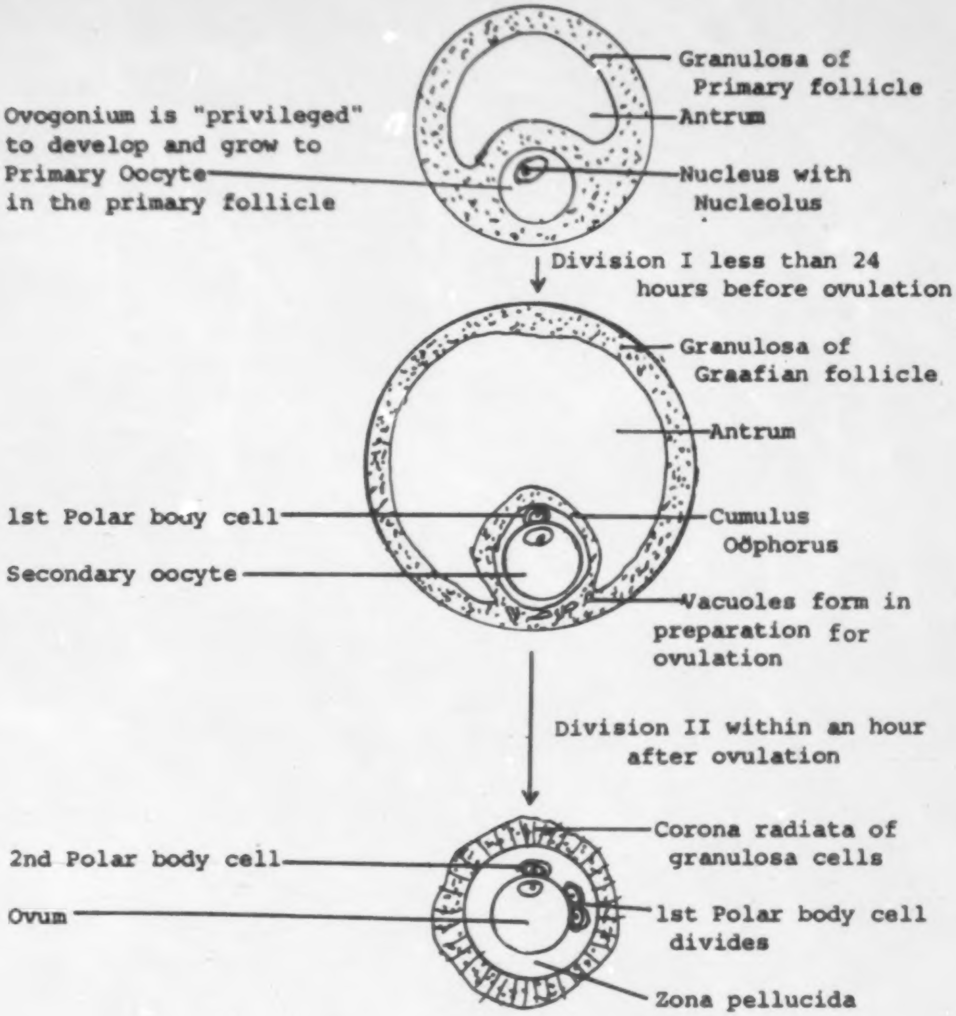
2. In the female (with emphasis on woman)

The primary sex cells multiply during fetal life so that there are about 5,000,000 in the ovaries of a newborn girl. After leaving the hormonal stimulation of the mother, these undergo atresia starting soon after birth so that at puberty (age 11 to 16 with a mean about 13) there are only a few hundred thousand left and by menopause (age 45 to 50) they are absent. The medical record for motherhood is about 35 pregnancies. This is just about the original number of primary sex cells that leave the primitive gut in early embryology. Nature is no less wasteful of female gametes in women than it is in many animals that have external development, but it takes infinitely more pains to see that when an egg is fertilized it will have a much better chance of survival.

The primary sex cells privileged to persist through reproductive life (they don't divide after 6 months post-partum) become encapsulated with mesenchyme cells. These mesenchyme cells grow to be cuboidal and since they have granular cytoplasms are called granulosa cells. Such an encapsulated cell is an ovogonium (Latin: ovo--egg, gonium--former; Greek: Oön--egg. Latin-Latin word would be ovogonium; Greek-Latin mixture would be Oögonium. Both are used.)

In most invertebrates, meiosis does not take place until after the egg has been entered by a spermatozoan (See Exercise 16 C).

In women the primary ovocyte persists up to ovulation. Meiosis I occurs within 24 hours before ovulation. Meiosis II occurs after ovulation and before spermatozoan entrance. The sequence is:


Granulosa of Primary follicle
Antrum
Ovogonium is "privileged" to develop and grow to Primary Oocyte in the primary follicle
Nucleus with Nucleolus
Division I less than 24 hours before ovulation
Granulosa of Graafian follicle
Antrum
1st Polar body cell
Cumulus Oöphorus
Secondary oocyte
Vacuoles form in preparation for ovulation
Division II within an hour after ovulation
Corona radiata of granulosa cells
2nd Polar body cell
Ovum
1st Polar body cell divides
Zona pellucida

Meiosis in the Mammalian egg follicle.

The ovum or egg

The term Ootid is sometimes used for unripe eggs (not ready for sperm entrance), but when Meiosis II occurs in woman the Ootid is already an ovum. Ootid is a morphologically fictitious stage created to parallel the spermatid, for the egg does not undergo any metamorphosis as does sperm.

Do Exercise 24, Histological Study of the Female Reproductive System, at this time to study the histology of the system and the sequence of follicle changes in the ovary.

C. Factors Affecting Mating and Ovulation

1. Invertebrates. In general the development and ripening of gametes is a function of water temperature, although the length of day may also be controlling factors. In some Nereids, the moon tide seems to be a factor. The male and female frequently will never meet. Gametes are released into the water. They are chemically attracted if they happen to get near enough to each other. Development of the offspring proceeds without the care or nurture of the parent.

2. Vertebrates

a. Fish. Many fish, usually the male build nests. A mating dance attracts the female and if she has ripe eggs, they are released and the milt (semen) is deposited, probably in response to hormones released with the eggs.

b. Amphibians. Newts have internal fertilization without copulation (the sperm are deposited in a capsule on a leaf, then the female "sits" on the capsule, taking it into the cloaca where it dissolves, releasing the sperm). Thus fertilized eggs are laid.

The frog employs amplexus. The male grasps the female from the back. There is a transfer of hormone from female to male, and when oviposition occurs the additional amount of hormone causes sperm release from the male. Thus the eggs are laid and fertilized within a few minutes. Usually the covering on frog eggs cannot be penetrated by sperm after about 15 minutes in the water.

This ability of female gonadotropin to cause sperm release in male frogs is the basis of the frog test for pregnancy. See Exercise 26 for procedure.

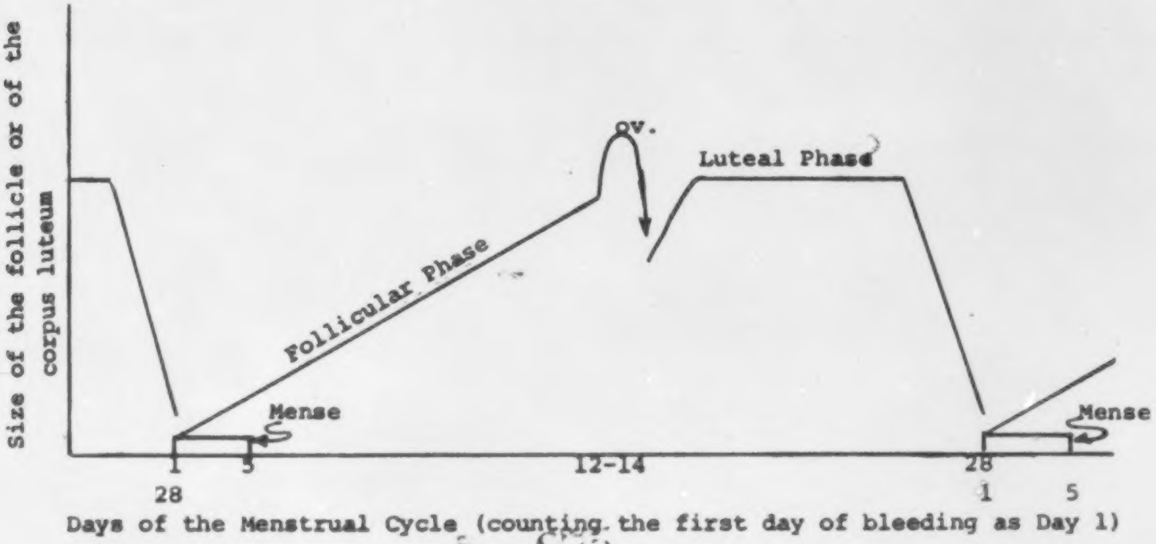
c. Reptiles and Birds. Reptiles usually ovulate and shell a group of eggs (perhaps a dozen) which are then oviposited (laid) on land (in the sand).

Birds usually lay their eggs in clutches of 1, 2 or more eggs. Both wild and domesticated birds respond to sight. If there are two eggs, and one is removed, the bird will lay another, and if that is removed, will lay another until a large number of eggs have been laid. Chickens usually lay about 5 to 20 eggs in a clutch in the morning hours. Removal of eggs from the nest is a stimulus to further laying, but also the presence of at least one egg (made of glass, for example) is a stimulus to laying. Birds and reptiles copulate by cloacal apposition.

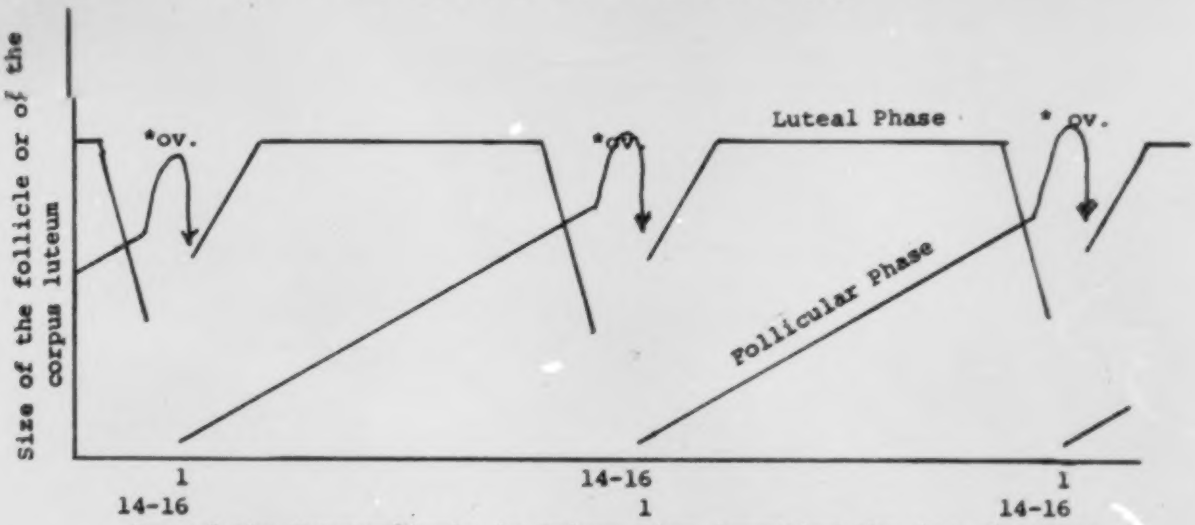
d. Hormonal Relationships in Mammals

The pituitary gland of woman secretes three proteinaceous hormones affecting the ovary and the development and release of eggs, and at the same time affecting physical readiness and psychological receptivity for mating.

Pituitary Luteinizing Hormone (LH) is responsible for the initiation of further development in the primary follicle. After the primary follicle acquires about 20 layers of granulosa cells spontaneously, LH acts to cause the formation of an antrum. This makes the follicle responsive to a second pituitary hormone, Follicle Stimulating Hormone (FSH), which causes the antrum to enlarge. When the antrum of the follicle is the dominant feature of the follicle it is ready for ovulation and is called a Graafian follicle (after Regnier de Graaf). At this point, LH acts again to begin the conversion of follicle cells from estrogen secretion under the influence of FSH to progesterone secretion under the influence of a third pituitary hormone, Luteotrophic Hormone (LtH). In the course of this conversion ovulation occurs as a sort of very regular accident. Following ovulation, the follicle is converted completely to its luteinized form, the corpus luteum, which secretes progesterone for changing the secretory activity of the uterus and the maintenance of pregnancy. The time sequence of these events is given by the following diagram. One technique of fertility control is to generate a high LH level, luteinizing the follicle so rapidly that the egg is trapped in the forming corpus luteum and so does not become available for fertilization.



Menstrual cycles are peculiar to the higher primates (monkeys, apes, gorilla and woman). Lower primates (lemurs, Elephatulus) and other mammals have estrous cycles. An example is found in the guinea pig.



Day of the Estrous Cycle in Guinea Pigs (counting the day of estrus as Day 1)

Note that in the guinea pig the follicular and luteal phases fall together. Ovulation occurs on Day 16 at which time the female is receptive, indicated by (*). At other times she repulses the male, and even closes the vaginal opening with a membrane to prevent copulation.

Rats and mice have a 5-day estrous cycle with about 4.5 days of follicular phase and .5 days of luteal phase, unless pregnancy occurs. But again females are sexually receptive to males only when in heat (estrous).

Domestic animals (cat, dog, horse, cow and pig) have a long period of anestrous, so that they come into estrous every 6 months, that is, a two to three week period during which the egg is ready for ovulation and awaits the stimulation of copulation to make it ovulate.

Contraceptive Steriods

A high level of LtH stimulates a high level of progesterone and the progesterone inhibits the release from the pituitary gland of FSH. Therefore, if a woman is given a high dosage of progesterone, follicles will not ripen and be sensitive to LH-induced ovulation. Those progestational steroids which are not digested in the stomach or intestine are commonly used for this purpose. Because it becomes increasingly hard to inhibit FSH, if ovulation does not occur when it should, the LH completes the luteinization of the follicle to a corpus leuteum, trapping the egg. After the egg is trapped, a menstruation is permitted by taking either estrogen or no additional progesterone. Menstruation is a tissue phenomenon resulting from the reduction of either estrogen or progestational support to the uterine lining.

D. Fertilization

1. Non-Copulating Invertebrates

a. The cortical granules in invertebrate eggs release a substance which activates sperm. This kind of substance is called a termone. Sperm also releases androtermones just as egg releases gynotermones. In these organisms fertilization begins with gamete attraction. The closer they are to the egg, the more vigorously the sperm swims.

b. Fertilization Processes

1) Sperm entrance. When the sperm makes contact with the egg, there is a reaction like an antigen-antibody reaction between the proteins on the surfaces of the gametes. The first sperm through the membrane is met by a reaction from the cytoplasm that engulfs it (the fertilization cone). At the same time the external egg membrane (the egg chorion) lifts up off of the egg surface, presenting a barrier to the entrance of more sperm.

2) The general rule for invertebrates is to lay their eggs when they are ripe (ready for sperm entrance) and then undergo the meiotic divisions. The sperm takes a position at rest in the cytoplasm while the egg nucleus undergoes meiosis at the periphery. When the second polar body cell is formed, the chromosomes of the haploid nucleus (the pronucleus) then undergoes prophase changes. The male nucleus also becomes vesicular and forms prophase chromosomes. The male brings the centrioles into the egg and these form a spindle into which the chromosomes from both the egg pronucleus and female pronucleus come to lie in the metaphase plate. At this point the process of fertilization has been completed. On anaphase movement, the separation of the chromosomes takes place and the first cleavage of the zygote is underway.

2. Copulating Invertebrates

a. Paramecium. See Exercise 20 for diagrams of conjugation in P. aurelia.

b. Tapeworms. Tapeworms are more like a colony of segments than a single individual. The anterior segments are male and the middle ones are female. The male segments copulate with the female segments and then the ovaries develop and the eggs are fertilized internally. The whole segment is released into the intestinal tract where it breaks up and the eggs are released. Tapeworms, therefore, are hermaphrodites.

c. Earthworms. These are classical organisms for the study of copulation among invertebrates in beginning biology classes.

Approach

Do Exercise 16C Meiosis (or review it).

3. Vertebrate Copulation and Fertilization

a. Fish and Amphibians (See section C)
b. Reptiles and Birds (See section C)

c. Man as an example in Mammals

Just as spermatogenesis in males is continuous, so are males continuously and aggressively ready to participate in mating activities with estrous female animals. In human beings, such readiness is offset by a number of psychological and social factors. That is, while hormones may drive rats to sexual activity almost involuntarily and only at times when fertilization is most likely to occur, mating activity among human beings (and other higher primates) is primarily a social activity which takes place privately and is under the control of the will. Reproduction is the relatively rare consequence of sexual activity in people, and even that possibility (about one day a month) is reduced by the appropriate birth control procedures or devices.

Under the appropriate psychic circumstances the penis is erected and inserted into the female vagina. The movements of the bodies of the participants produce a friction on the penis which causes the reflex ejaculation of semen.

After the spermatozoa are metamorphosed in the testis, they pass through the epididymis, a series of tubules about 100 feet long. This trip takes 30 days, during which the sperm ripen (become more capable of fertilizing an egg). They are carried along by cilia in the tubes. They are then carried (partly stored) in the ciliated tubes of the ducti deferenetia (sing.-deferens)). Sperm collect at the junction of the ducti deferentia and the urethra, the ampulla. At ejaculation, secretions of the seminal vesicles and of the prostate gland are forced out with the sperm. The seminal fluid contains the sugar fructose which activates the sperm to swim actively. The prostate gland contains a lot of phosphatase, no doubt functioning in the availability of phosphate for ATP regeneration, since that material is used to power the sperm tails.

The semen helps buffer the sperm medium against the acidity of the vaginal contents. Sperm deposited near the vaginal orifice may or may not survive the trip to the uterus. Most usually at orgasm, the semen is deposited at the cervix. The expansions and contractions of the uterus suck the sperm inside up to the oviducts. This transport of sperm takes about 6 hours in woman.

The ovum, when liberated from the ovary, is thrust out of the ovarian follicle together with the follicular liquor, a layer of granulosa cells (the corona radiata). This mass of cells is picked up by the fimbria (fingers) of the Fallopian tube (oviduct) and transported to the end of the oviduct near the uterus. There is a sphincter at the utero-tubal junction which keeps the egg from entering, but sperm may pass. The ovulated egg will remain viable (fertilizable) about 24 to 48 hours. It is normally fertilized in the oviduct and there it remains for about 7 days. If the egg is not fertilized it still remains in the oviduct. The difference is that it dies, and is reabsorbed without ever seeing the "promised land" of the uterine lining. If fertilized, it will probably develop to the gastrula stage before the progesterone from the corpus luteum has changed the uterine lining to a secretory one suitable for feeding the embryo. At 7 days after ovulation the tubo-uterine sphincter opens and the blastocyst enters to be implanted.

Each sperm carries a molecule of the enzyme hyaluronidase, which helps dissolve the intracellular cement between the cells of the corona radiata. For this reason about 60 million sperms are needed for fertility in man. When the corona has been digested through, then one sperm fertilizes the egg, and the fertilization membrane rises to prevent further entrance of sperm. If they enter they are not used. All known fertilizations occur in watery environments, even those in flowers.

4. Conception Control

a. Ligation or cutting of ducts (sterilization). By tying tightly the ductus deferens, sperm can be prevented from entering the semen. Eggs developing beyond the blastocyst stage in the oviducts (tubal pregnancy) would be fatal, so a tight ligation of the tubes is necessary. It has been standard practice to also cut the ductus deferens, but more recent technique makes use of tight silver or other metal clips which can later be removed at the time fertility is again desired.

b. Spermatocides. Various preparations which change the pH and in other ways make the environment fatal to spermatozoa are used within the vagina. These are usually prepared as foams, jellies or creams to stabilize the dispersion of the spermatocide and to make for easier handling.

c. Occlusive or Mechanical devices include the condom placed over the penis to catch the semen, or the diaphragm, placed over the uterine cervix to prevent sperm entrance.

d. Inter-uterine devices or pessaries have been used for a long time, in fact before people knew what they did. There is danger of some of them perforating the uterus. They are occlusive, but are placed in the uterus to create a state of pseudopregnancy (false pregnancy), which supports the corpus luteum and thus prevents ovulation.

5. Human Placentation

Implantation refers to the embedding of the developing blastocyst in the wall of the uterus. The progestational uterine lining secretes glycogen and "uterine milk" to nourish the blastocysts for about a week. It is now almost two weeks after ovulation and the corpus luteum will no longer respond to pituitary LtH, but the corpus luteum will respond to chorionic gonadotrophin for the term of the pregnancy. Implantation occurs about day 12 after ovulation. In woman, the entire blastocyst becomes covered when it sinks in (nidation). The chorion begins to secrete sufficient human chorionic gonadotropin (HCG) to support progesterone secretion by the corpus luteum.

When the uterine lining comes under progesterone influence just after ovulation, the arteries begin to coil (to slow down the blood) and sinusoids develop near the surface. Upon implantation, the chorionic villi push through the walls of these sinusoids, so that the only barrier between the maternal blood and the embryonic blood is a layer of chorion and a layer of fetal endothelium (the capillary wall on the embryonic side). In other mammals there are 3, 4, or 5 layers separating the maternal and embryonic blood. The thinness of the barrier contributes to the efficiency of diffusion.

Approach: Do Exercise 26, Response of Animals to Pregnancy Urine Hormone

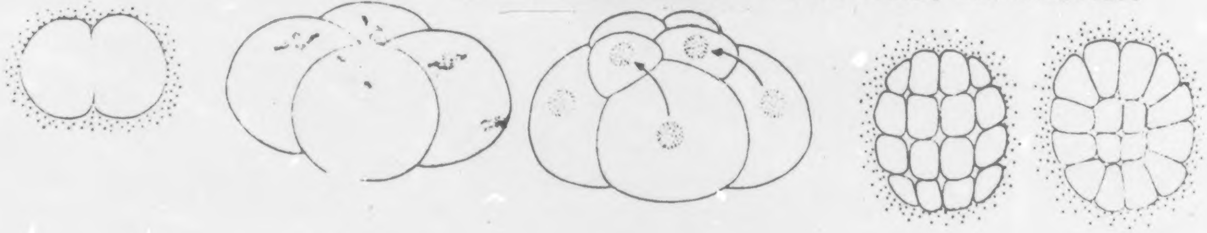
IV. Development

References
Sussman (1964) Chap. 4
Patten (1964) Chap. 5
Ortho (1968) Chap. 3
Kerr (1967) Chap. 4

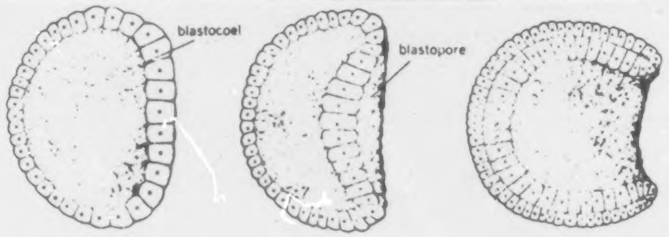
A. In Amphioxus

Amphioxus, the lancet is a prochordate, whose developmental pattern consists of a number of clear stages. Such stages become somewhat telescoped in human embryology.

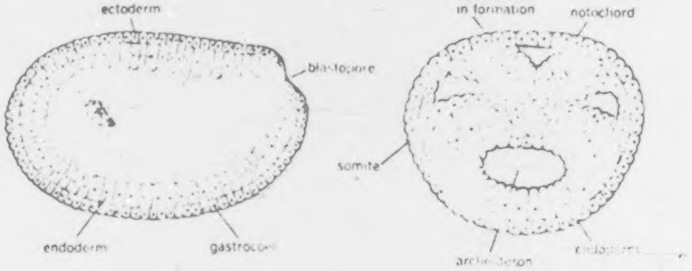
Cleavage of the zygote results in a hollow ball of cells, the blastula.



The blastula begins to grow on the outside, pushing some of the cells inward like a collapsed ball. The growth of cells over the edge of the blastopore results in the elongation of the embryo and the organizing of cells for the notochord.

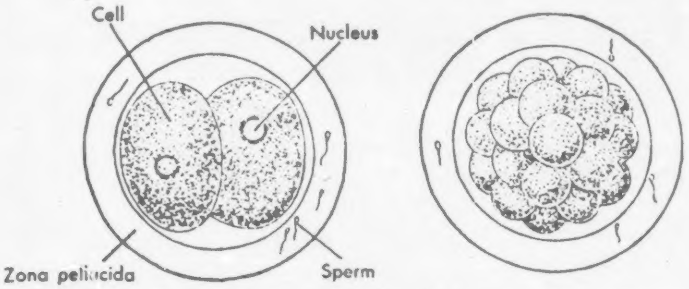

blastocoel
blastopore

As cells pass over the dorsal lip of the blastopore (the primary organizer) they come in contact with the inducing substances. The notochord organizes the neural plate in the ectoderm and the somites in the mesoderm. The mesoderm forms the kidney (pronephros) laterally then splits to form the dorsal somatic mesoderm and the ventral splachnic mesoderm.

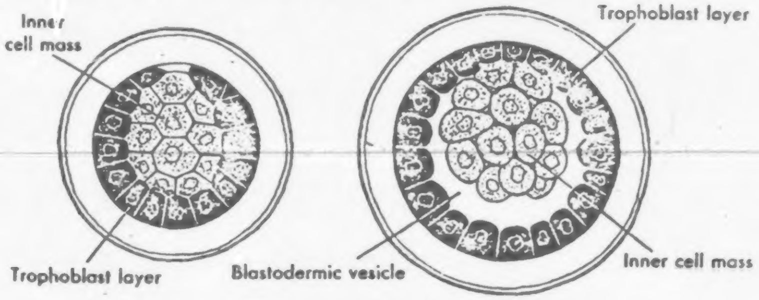

ectoderm
blastopore
endoderm
gastrocoel
neural tube in formation
notochord
somite
archenteron

B. In Man

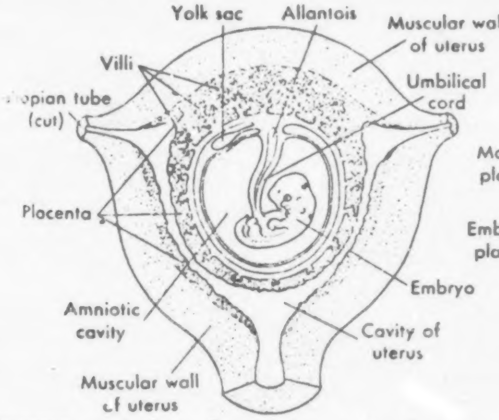
Cleavage of the egg results in a solid mass of cells (the morula or mulberry). A cavity forms and expands. This results in an inner cell mass, which is the embryo, and a layer of cells around a cavity (the empty yolk cavity), which is called the trophoblast. The cavity is the blastocoele.

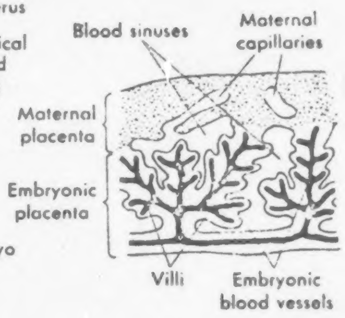

Cell
Nucleus
Zona pellucida
Sperm

The entoderm splits off the bottom of the inner cell mass and thus covers the primitive gut (blastocoel). The cephalic and caudal margins become differentiated, with a mesoderm proliferating area caudally. This is actually the Hensen's node which will generate the notochord forward under the ectoderm of the embryonic disc (top layer of the inner cell mass).


Inner cell mass
Trophoblast layer
Trophoblast layer
Blastodermic vesicle
Inner cell mass

The notochord induces the head, neural tube, somites, and these in turn generate the intermediate mesoderm, and the somatic and splanchnic mesodermal layers which enclose the coelom.


Yolk sac
Allantois
Muscular wall of uterus
Villi
Umbilical cord
Fallopian tube (cut)
Placenta
Embryo
Amniotic cavity
Cavity of uterus
Muscular wall of uterus


Blood sinuses
Maternal capillaries
Maternal placenta
Embryonic placenta
Villi
Embryonic blood vessels

2. Organs arising from the germ layers
   a. Ectoderm: brain, nervous system, skin
   b. Mesoderm: muscles, bones, heart and blood vessels, lungs, kidneys
   c. Mesenchyme: blood
   d. Entoderm: intestinal tract, liver, pancreas

3. Placental Functions

a. The placenta brings about the exchange of food, oxygen, vitamins and other needs carried by the blood with the blood of the embryo without mixing many of the large proteins (some antibodies are permitted to pass).

b. The placenta secretes chorionic gonadotrophin, which maintains the corpora lutea, estrogen secretion, and progesterone production (in the placenta) which together with that from the corpus luteum, maintains the uterine lining in a condition needed for pregnancy, and keeps the uterine muscle still, so that the fetus will not be born before time. Human beings have a high estrogen, high progesterone level during pregnancy, whereas some other animals only have high progesterone (rat, mouse, etc.). Therefore, high estrogen cannot be used to bring about an abortion of human pregnancy.

c. The chorion frondosum changes at the third month of gestation to the chorion laeve (smooth). This makes this a high-risk time for aborting the pregnancy (miscarriage). The fetus can be dislodged or it may die, resulting in natural abortion of the pregnancy.

4. Parturition

As gestation approaches term (40 weeks), the epithelial chords work their way down from the lumen of the cervix. At term the corpus luteum becomes non-functional, and in the absence of progesterone, and in the presence of estrogen, the uterus begins to contract. Oxytocin from the posterior pituitary gland also is released and increases the strength of the uterine contractions. These contractions (as strong contractions in any tubular organ--intestine, stomach, etc.) are painful. Pressure is normally from the fundus toward the cervix. Abdominal muscles help, as the fetus is pushed head first down against the cervix. The epithelial cords split, thus greatly enlarging the cervical os (mouth). The baby is finally pushed through. It must be received, the umbilical cord tied off and cut, and the breathing reflexes started, if they do not start spontaneously. Sometimes, pinching of the umbilical cord will cut off the blood supply to the baby before he can start breathing, resulting in a stillbirth. The placenta is born a few minutes after the baby, the so-called "after-birth". If all has gone well, there will be a healthy baby. After inquiring about whether it's a boy or girl and its color, everyone wants to know if their baby was made alright.

5. Lactation and Nurture

Within 24 hours after parturition, a follicle that has grown up to the pre-ovulatory state will ovulate, forming the "corpus luteum of lactation". Progesterone brings about the accumulation of the milk in the mammary glands, and oxytocsin from the pituitary acts to make the milk-laden acini contract, and thus squeeze out the milk (milk let down). Nursing the baby causes a reflex between the nipple and the uterus to make the uterus contract during this period and resume a smaller size. Babies, in any event, need both love and a good diet during their early months in order to realize their human and intellectual potentials later in life.

V. Life Cycles

Programmed Materials:

Humphrey, D. G., H. Van Dyke, and D. L. Willis. 1969. *Student Guide with Programmed Units for Life*, Shorter edition. New York. Harcourt, Brace & World, Inc.

The Human Body and Its Functions. A programmed course. Encyclopedia Britannica Press, 1964. 425 North Michigan Avenue, Chicago.

The Physiology of Conception and the Oral Contraceptives. A programmed instruction course. Developed by Medical Programs Incorporated, 1968. Medical Programs, Incorporated, 200 Park Avenue South, New York, N.Y. 10003

Methods of Conception Control. A programmed instruction course. Ortho Pharmaceutical Corporation. Raritan, New Jersey. Revised, 1967, by Medical Programs Incorporated.

Films:

Boy to Man. Massachusetts Department of Public Health. This film presents the changes of adolescence in order of their simplicity, i.e., moving from the superficial changes of growth, skin, voice and body hair, to the more complicated phenomena of glandular changes and sexual maturation. Throughout the film normality is portrayed. Individual differences in rate of growth are stressed as normal. 18 min.

Girl to Woman. Massachusetts Department of Public Health. The film presents the changes of adolescence, moving from the superficial changes of growth, skin, body hair and body contour to the more complicated phenomena of glandular changes, sexual maturation, and the reproductive function. Through the film, individual differences such as those in rates of growth in menstrual cycles are stressed as normal. The importance of sound habits of personal hygiene and health are highlighted.

From Generation to Generation. Massachusetts Department of Public Health. This sensitively made film, combining animation with live action, illustrates the basic facts of human reproduction, showing childbirth as an emotional and spiritual experience as well as a physical one.

The Bryophytes. McGraw-Hill Films. Our Living World Series. The film details the asexual and sexual life cycle of the moss and explains formation of peat bogs. 16 min.

Ferns and Their Allies. McGraw-Hill Films. Our Living World Series. Studies sexual reproduction of ferns and alternation of generations both diagrammatically and by viewing actual specimens.

Gymnosperms. McGraw Hill Films. Our Living World Series. Traces development of pine seedlings to the production of the two types of cones. Explains development of the micro- and macrogametophyte, and of the zygote and embryo. Shows reproductive cycle of the Ginkgo and the cycads. 16 min.

Self-Tests

The specific reference, Life, by Simpson and Beck, has an accompanying Student Guide with Programmed Units, by Humphrey, Van Dyke and Willis, published by Harcourt, Brace and World. It is suggested that the Self-Tests of this Student Guide that parallel each section of specific reading listed in the unit outline should serve as excellent self-test material.

A. Alternation of Sexual and "Asexual" Generations

Now that we have some examples of reproduction without respect to sex, and sexual reproduction, we may go back and see how these two forms of reproduction fit together in nature.

Some strains of protozoa may reproduce without respect to sex for many generations without undergoing conjugation. Three patterns of these kinds of life cycles are given in Exercise 20 in the laboratory manual (See Teacher's Guide to Exercise 20).

Haplontic patterns are the most primitive. Diplontic patterns alternate in the life of the organism with "asexual" phases.

Approach

Do Exercise 20	Asexual (reproduction without respect to sex) and Sexual Reproduction

B. Alternation of Sporophyte and Gametophyte Generations in Flowering Plants

Approach

Do Exercise 21	Reproductive Structures in Flowering Plants
Exercise 22	Seed and Fruit Production in Flowering Plants
Exercise 23	Monocot and Dicot Seeds, Seedlings and Leaves

See also Teacher's Guide to Exercises 21, 22, and 23.

VI. Regulation of Growth and Development

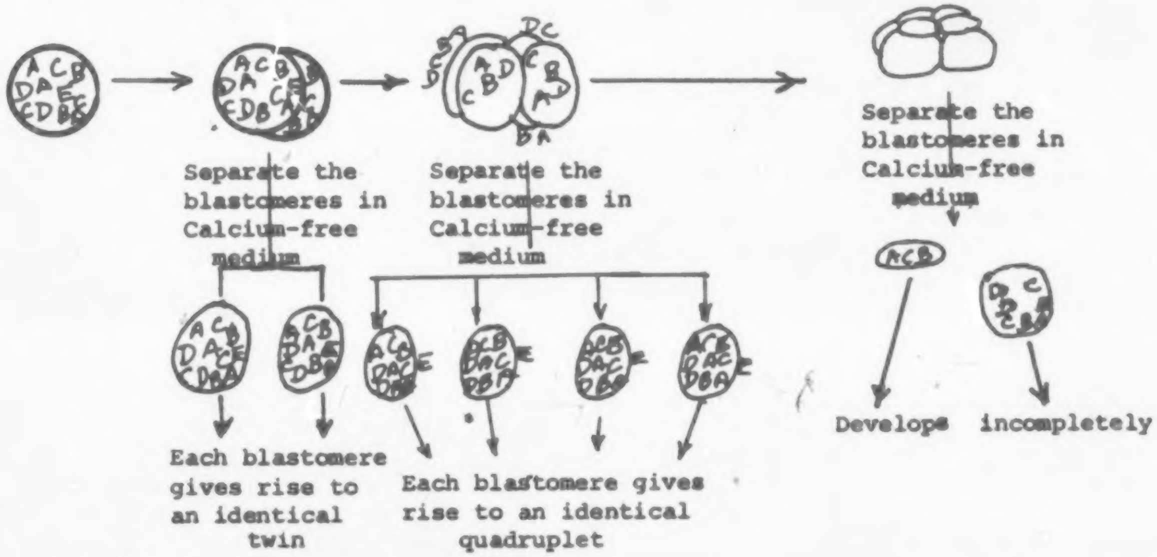
Specific Reference
    Sussman (1968) Chap. 7
    Kerr (1967) Chap. 5, 6 and 7
Other References
    Balinsky

A. Chemodifferentiation

1. Each permanent morphologic change (differentiation) is preceded by the marshalling of the materials needed for that change (called determination). The organizing tissue transfers materials (found by Brachet to be RNA) to cells, determining their future. With a brief lapse of time for the activation of a gene cistron, the exposed genes form new products (in the cytoplasm) needed for the differentiation.

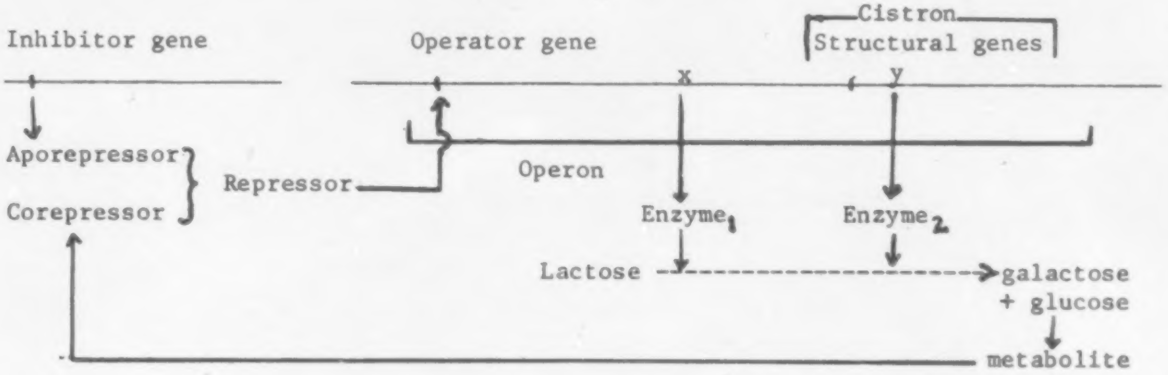
2. Mosaic and Regulative Eggs
Some eggs of the lower invertebrates are so chemically organized that one can indicate on the egg surface the parts which will give rise to each of the embryonic tissues. These are called mosaic eggs. If a part of the egg is cut away, the embryo will be missing the projected part.

Other animal eggs do not become this well organized until after development (cleavage) has started. Human eggs are in this group as are the eggs of sea urchins and frogs.
These are regulative eggs.


Separate the blastomeres in Calcium-free medium
Separate the blastomeres in Calcium-free medium
Separate the blastomeres in Calcium-free medium
ACB
Develops incompletely
Each blastomere gives rise to an identical twin
Each blastomere gives rise to an identical quadruplet

1. Adaptive Enzymes
The concept from experimental embryology is that each cell comes to have a certain chemical constitution which is able to activate a gene cistron. The resultant enzyme (protein) synthesis is said to be adaptive emzyme synthesis

because it is increased by certain metabolites in the cell. This was first shown by Clausen (1961) and Zalokar (1961) who found that the insect steroid hormone, ecdyson, caused chromosome puffing (and concommitant gene exposure). Later Jacob and Monod (1961) working in Lwoff's laboratory in Paris, demonstrated that lactose could be used this way by the bacterium E. coli.

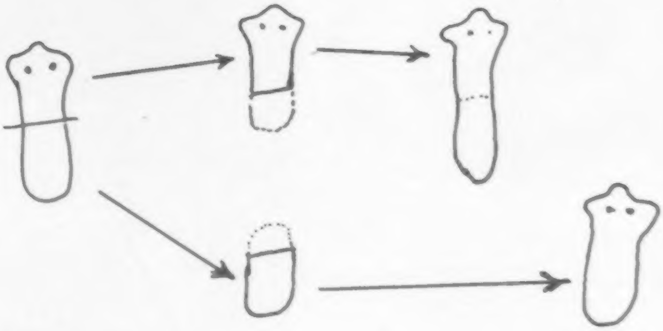


If all the glucose is used up, then no metabolite is present and the metabolite cannot act as a corepressor to form the repressor. Since there is no active repressor, the operator gene will therefore activate the structural genes that enable the cell to utilize lactose.

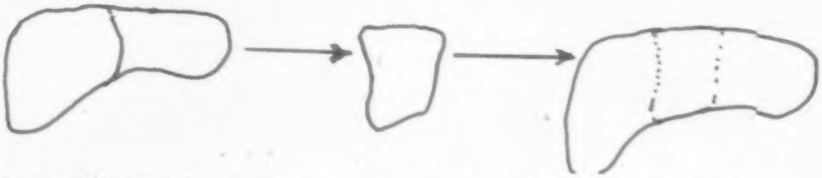
In this way, as new metabolites are formed, they derepress new operator genes, activating new cistrons forming enzymes which provide products (metabolites) for differentiation and for derepressing new operons.

2. Differentiation proceeds according to the influence of neighboring cells on each other. The result is as though an imaginary blueprint existed for the form of the differentiating part. The cells grow out to fill the blueprint and no further. The concept of a gradient field is that the distance from the organizer sets up a graded field for some substance needed to determine a differentiation.

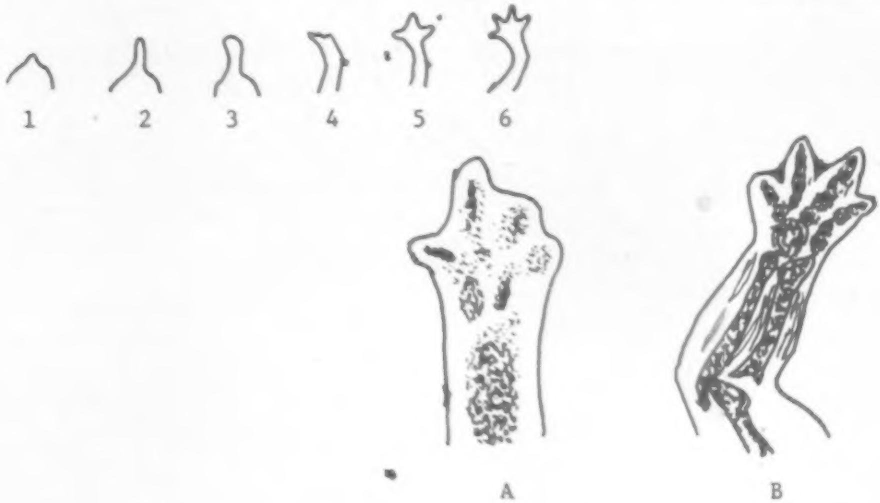
3. Evidence for the gradient field concept comes from observations of regular development and also from regeneration experiments on Dugesia and salamanders. Mammals can regenerate certain tissues (liver, adrenal cortex, etc.) but not body parts such as legs, arms, eyes, etc.



Front-rear regeneration in a bisected Planarian. The gradient field is the size of the normal Planarian so that the regenerated part is not larger nor smaller to any significant degree than the normal.

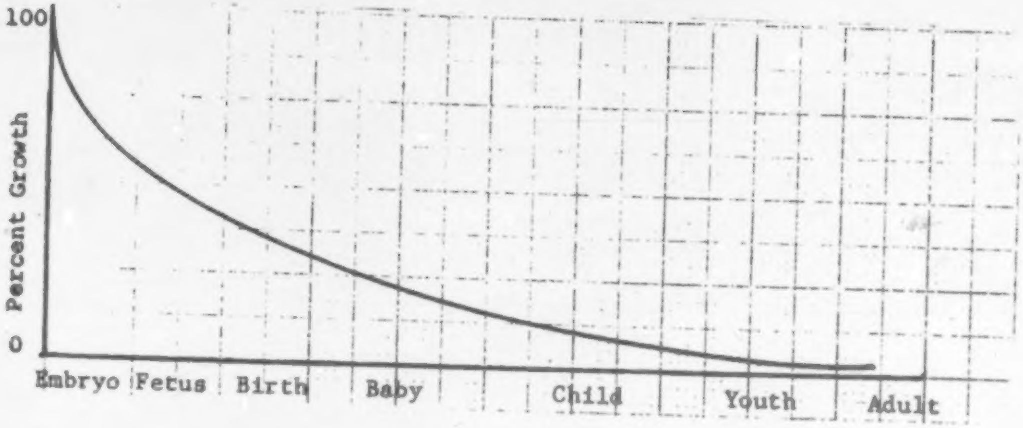


About 3/4 of the mammalian liver can be removed without it being fatal (if properly done). The liver grows very rapidly, many cells becoming multinucleate during the process. Finally, the liver is returned to its normal size and shape.



Regeneration in the extremities of the salamander, Triturus taeniatus. Regeneration of the forelimb is shown at 1 to 6. A--Differentiation of skeletal parts in the right hind leg. B--Advanced differentiation in the left forelimb. (After Fraissse, 1885 in Nicholas, J. S., 1955)

C. Stimulation of Growth

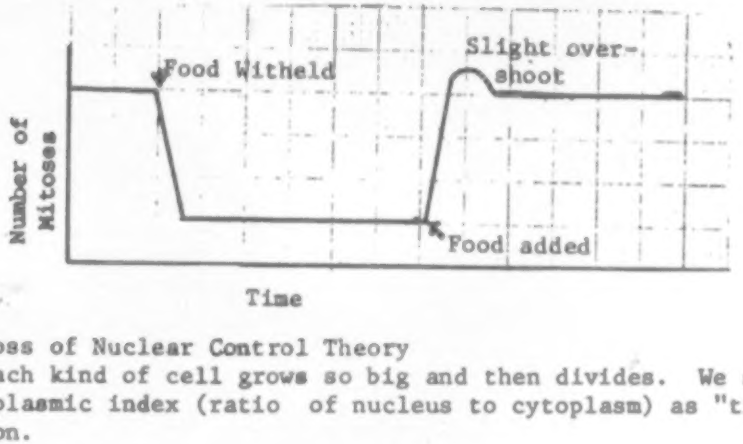


The embryo has a tremendous relative growth rate in man. This becomes progressively less with time until adulthood is reached. The pre-natal care of the mother is important to the child. Drugs which slow down division of some cells result in defective children (Thalidomide was a popular offender in the 1960's). Because the placenta cannot keep out drugs such as narcotics, babies can be addicted to these and undergo withdrawal symptoms at birth. Normal stimulants for cell division are good nutrition and trophic hormones.

1. Nutrition

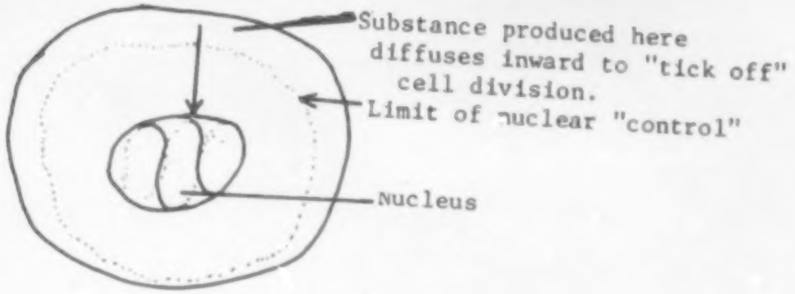
A good diet is essential for the normal development of a child even after it is born. Before birth it can draw on the mother for foods, salts and vitamins. After birth, lack of a good diet (milk--calcium--and vitamins) can result in slowed down nerve cell division in the brain with resultant mental retardation.

We can follow the number of mitoses in a cell culture as a measure of growth. These results are obtained for a wide variety of cells.



2. Loss of Nuclear Control Theory

Each kind of cell grows so big and then divides. We speak of the nucleo-cytoplasmic index (ratio of nucleus to cytoplasm) as "ticking off" cell division.


Substance produced here diffuses inward to "tick off" cell division.
Limit of nuclear "control"
Nucleus

The theory is that the nucleus controls synthesis in a normal volume of cytoplasm. When that volume is exceeded, "uncontrolled" processes in the peripheral cytoplasm generate substances which starts prophase. This is still just a theory (Mazia and Dan, 1952).

3. Hormones. The Hormone-Gene Hypothesis

We have already indicated that steroid hormones appear to activate genes. This is the hormone-gene hypothesis. Many hormones stimulate growth (protein synthesis) in their target cells. It is also possible they increase membrane permeability to foods and thus bring about better cell nutrition and growth.

4. Carcinogens

There are a number of chemicals that cause more rapid cell division (cancer). Therefore they are called carcinogens (cancer producers). The tar products of coal and tobacco are in this group, as are certain alkylating agents such as mustard gas. Physical agents such as X-rays, isotope irradiation, rubbing and abrasion over a period of time, will also cause some cancers. Simple rubbing will cause benign cell division in the skin causing callouses and corns (by metaplasia).

Viruses also cause cancers (leukemia) and are responsible for the skin growth called a wart. In these cases, the nucleic acid of the virus is causing protein synthesis, growth, exceeding the nucleocytoplasmic index and (poof!) cell division!

D. Suppression of Growth

1. General Application

From what has been said of thalidomide and of other drugs, growth can be slowed down. This is the basis of some cancer chemotherapy. Rapidly-dividing cells are most susceptible to certain drugs. Blood marrow cells also divide rapidly. The technique is to withdraw about a cupful of marrow from the hip bones, give the poisonous chemical which kills both the cancer and the remaining marrow. In 2 to 3 days the drug has been eliminated by the kidneys. The cancer is dead, and the marrow is put back into the bone cavities where it grows and eventually repopulates all the blood-forming spaces (in about 4 to 6 weeks).

2. Alkaloid Drugs - Colchicine

Colchicine has the peculiar property of destroying the mitotic spindle. As a result dividing cell chromosomes enter the metaphase plate and can go no further. This makes it convenient if one wishes to note the number of mitoses in a tissue in a given time. However, it will kill the dividing cell.

3. X-rays and Isotope Radiation

In relatively moderate doses these radiations can cause cancer. However, they exhibit the "drug-effect" -- in larger dosages they kill. The disorder is "radiation sickness", and is characterized by malaise, nausea, and bleeding from the ears, eyes, nose and mouth. Ecologists think that too much radiation is bad for man and other living things. On the other hand, radiation is used to kill cancers and thus has saved many lives, too.

DISCUSSION QUESTIONS

1. What is the major disadvantage of "asexual" reproduction? Is this always a disadvantage?

2. Explain why meiosis is a necessary part of the life cycle of any sexually reproducing organism.

3. At what points in the life cycles of different plants does meiosis occur?

4. Describe the basic life cycle of higher plants involving alternation of generations. What are its adaptive advantages? How has availability or nonavailability of water affected the reproductive evolution of plants?

5. Describe the basic life cycle of seed plants. In what ways is this pattern particularly advantageous for terrestrial life? Describe the structure and adaptive significance of a flower.

6. Compare the process of gametogenesis in the male and female vertebrate animal.

7. In an animal with a diploid number of twenty chromosomes, how many are present in a spermatogonium? In a spermtid? In a primary oocyte? In the second polar body? In a sperm? In an ovum?

8. Describe the general structure of a mature human sperm and of a mature egg.

9. In the case of human beings how does the quantity of sperm cells produced compare with the quantity of egg cells? How is this significant?

10. Define oviparity, ovoviparity, viviparity. What vertebrates typically show each type of parity?

11. Trace the path of a human sperm from the testis to its union with the egg.

12. Describe the mechanisms that play a role in the normal transport of sperm through male and female genital tracts. Cite any naturally occuring deterrents to sperm transport and movement.

13. Describe various agents and methods that may block egg transport or sperm movement.

14. Distinguish among these terms: copulation, insemination, fertilization.

15. Compare the advantages of internal and external fertilization. Name some animals in which each occurs.

16. Describe the metabolic changes that occur in an egg immediately after fertilization.

17. What events occur during the cleavage of an egg?
Distinguish between identical and fraternal twinning.

18. Give illustrations of how the amount of yolk present in a fertilized egg determines the course of cleavage patterns to gastrulation.

19. Describe the sequence of events from fertilization to the completion of neurulation in Amphioxus.

20. Which structural tissues and organs of an adult vertebrate develop from each of the primary germ layers?

21. Discuss the formation and functions of these extra-embryonic membranes in reptiles, birds, and in mammals: the yolk sac, amnion, chorion and allantois.

22. Define morphogenesis, differentiation, growth, determination, polarity.

23. Explain the concept of embryonic induction. How are the neural plate and the eye induced?

24. What are "organizers"? How may they be involved in the control of development?

25. In what different ways may a fetal child in utero acquire a) nutrients and b) respiratory gases?

26. Review the structure of the human placenta and the embryonic and maternal blood circulation through it. Describe the whole pathway of the embryonic circulation.

27. What is a fetus? What are some of the striking changes that occur in the fetus at the time of birth?

28. Describe the events of parturition in the human.

29. Distinguish between seasonal cycles and fertility cycles.

30. What effects does castration have on human males and females?

31. In what ways are estrus and menstrual cycles different?

32. What happens to an unfertilized egg when it enters the uterus?

33. What effect do estrogen and progesterone have on the human female reproductive tract?

34. What are some of the physiological changes that take place at the onset of puberty in girls and boys?

35. What is the role of enzyme induction in development?

A classroom account from Mrs. Elizabeth D. Clark, North Carolina A & T State University

We introduced the students to Unit 4--Reproduction, by doing Exercise 37--Influence of Thyroid Hormone on Rate of Development. We ordered and received large bullfrogs and tadpoles from the supply house for this purpose. Teachers in the regular program said that they had set up a similar project last summer, but the tadpoles did not develop rapidly.

We set up the seven tanks of tadpoles with seven different developmental stages in each tank. We classified the tadpoles from the largest (#1) to the smallest (#7) according to the length of the body, length of the tail, and shape and size of the mouth. We also measured the legs and counted the joints thereon. We noted the color changes in the tail and feet. The tail and limbs of the experimental tadpoles were red but as they developed, they took on the normal color of the rest of the body.

One student asked if something could happen genetically to change the color of the frog. This question brought up a discussion of gene-enzyme relationship which we decided to emphasize under genetics.

Our tanks and concentrations of chemicals/liter of pond water was as follows:

A. 100 micrograms of thyroxine/liter of pond water.
B. 40 micrograms of thyroxine/liter of pond water.
C. 40 micrograms of triiodothyronine/liter of pond water.
D. 10 micrograms triiodothyronine/liter of pond water.
E. 8 micrograms of iodine/liter of pond water.
F. 4 micrograms of iodine/liter of pond water.
G. pond water control.

We followed through the experiment cleaning, changing the solutions and feeding the tadpoles daily.

Within three days we had positive development of limbs and feet, even on the smaller tadpoles in the experimental groups. It was of interest to note that there were no dead tadpoles for a week or more. All of the animals in tank C died and later those in tank D died.

The tadpoles in these tanks had developed fastest.

The possible reasons given for their death were:

1. The growth rate of the tadpoles exceeded their metabolic rate, so they died. No energy was left for maintaining normal life activities.

2. Something may have accidentally been placed in the tank that killed the organisms.

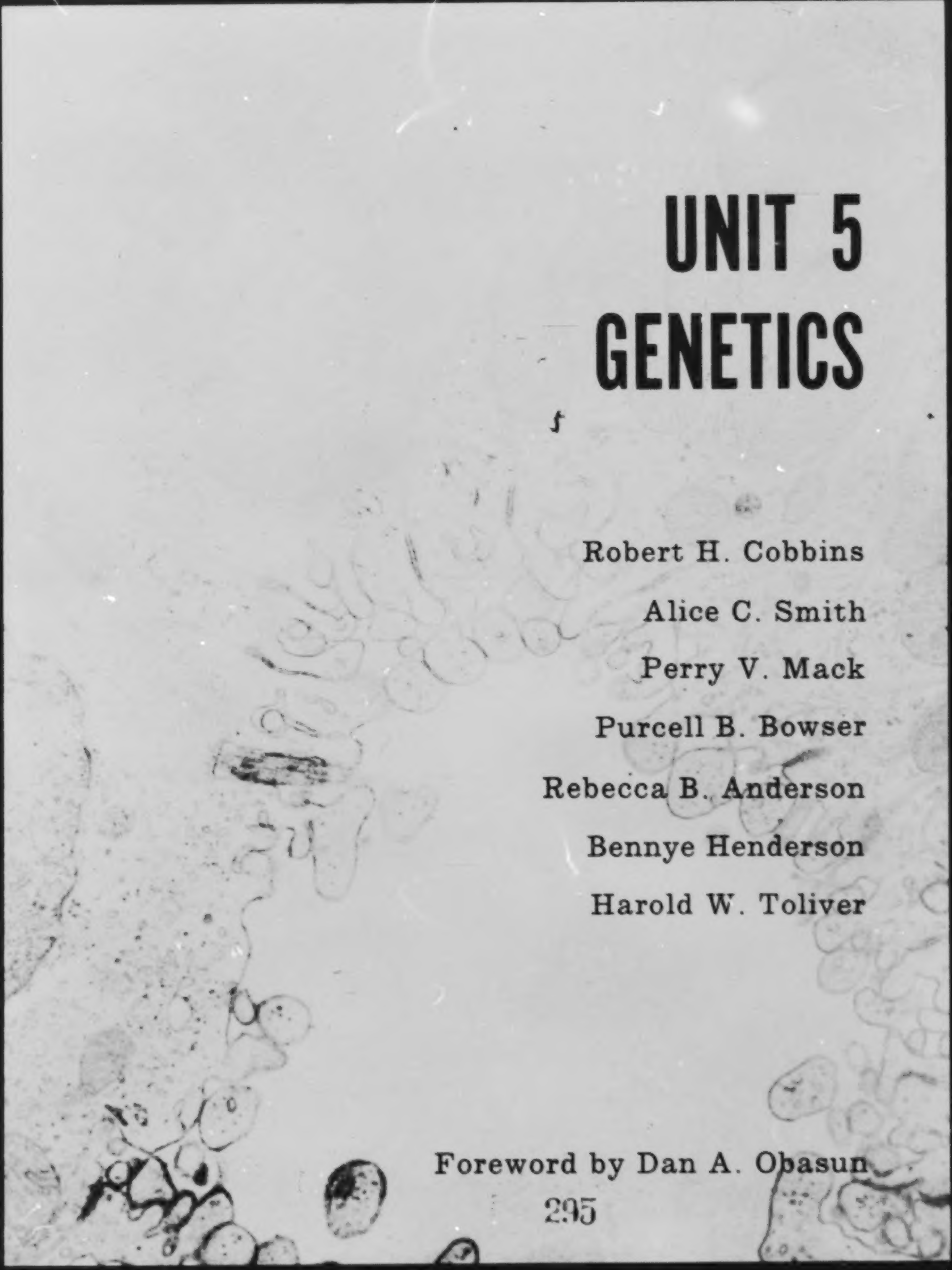
We placed the dead tadpoles in 70% alcohol and dated them so that we could determine how long it took for other tadpoles to reach that stage of development.

The characteristics to be observed were listed across a sheet of paper. The progess in each tank was recorded using a plus (+) or a minus (-) sign and the date.

The rest of the tadpoles are still developing. The classes this semester will chart the present development. We used hormones to initiate the development but after Feb. 8, 1971, we did not use any hormones in the tank of water, only pond water in each tank. We wanted to know if the early initiation of growth will cause the frogs to mature more rapidly or whether this early growth will be balanced by the normal period of rapid growth in the control group.

Members of the department looked with interest on this project and called attention of some other Biology students to the same.

Three tadpoles had the tips of their tails torn away. We observed regeneration in these regions. The uneven irregular ends became smooth and more rounded as cells differentiated.



UNIT 5
GENETICS

Robert H. Cobbins

Alice C. Smith

Perry V. Mack

Purcell B. Bowser

Rebecca B. Anderson

Bennye Henderson

Harold W. Toliver

Foreword by Dan A. Obasun

FOREWORD

It is not unusual for students to ask why they have to study genetics or some other fields of biology. This arises because some teachers have been under the impression that relevancy is secondary to the basic knowledge of genetics. This need not be so, because may of the principles of genetics espoused through the use of Drosophila and the microbes have their counterpart in man and other higher organisms. It should be shown how genetics relates to human development, thus making it relevant to the student himself.

While using other organisms as examples, a teacher should show the student how changes in these or other organisms affect man and his future generations. By generating curiosities about human nature one is bound to ask why John is different from Joseph, why man is different from a snake, etc. These examples will then lead to the basic principles of genetics which whould include the explanations for the following:

The nature of the biological material that is transmitted.

How the genetic material is transmitted.

The organization of the transmittted material.

The effects of the transmission from one generation to another.

Dan A. Obasun, M.S.
Department of Biology,
Northeastern University,
Boston, Massachusetts

GENETICS

INTRODUCTION

The survival of any race depends on its ability to propogate (reproduce itself). The chief function of the reproductive process is the perpetuation of the species. Regardless of how simple or how complex the reproductive process may be, it involves the transmission of genetic information from one generation to the next. The science of genetics is devoted to the study of the mechanisms by which hereditary potentials are transmitted from one generation to another and how they are expressed in a given environment.

Heredity is an outgrowth of reproduction. Its existence has long been recognized, but an understanding of its operation is comparatively recent. The first scientist to give us true insight into how heredity works was Gregor Mendel. He published a description of his experiments with peas in 1866, but 35 years passed before his work was appreciated. As a result of his experiments, Mendel came to several significant conclusions--conclusions which are still valid.

The biology teachers in the curriculum programs have found that the unit on genetics has proven to be of great interest and enthusiam. Being cognizant of this, the presentations are designed to stimulate discussion and create an understanding of the methods employed in scientific research.

To achieve these aims, the following objectives will be sought in the teaching of this unit:

Acquaintance with the basic concepts included in Mendel's Laws--with emphasis upon their relation to human genetics.

Becoming aware of the experimental evidence upon which the science of genetics is based, e.g., nuclear theory, chromosomal behavior, etc.

Learning the mathematical relationships underlining inheritance of characters.

Understanding of the current concepts of the genetic material (DNA) and its function in the cell.

.PROGRESS INVENTORY

1. Which of the following are not inherited?
    a. a pleasant disposition
    b. muscular size
    c. hemophilia (bleeding disease)
    d. blood type
    e. All of the above

2. Which of the following characteristics are inherited?
    a. musical ability
    b. sickle cell anemia
    c. obesity (fatness)
    d. laziness
    e. All of the above.

3. Genes and the inherited characteristics are the same.
    a. True
    b. False

4. All mutations are harmful.
    a. True
    b. False

5. X-rays produce mutations (changes in genetics).
    a. True
    b. False

6. More males are color blind than are females.
    a. True
    b. False

7. Blood is the basis of inheritance.
    a. True
    b. False

8. Changes in the Y chromosomes would only show up in males.
    a. True
    b. False

9. The gene, as we know it, is made up of:
    a. DNA-protein
    b. RNA-protein
    c. Messenger RNA (mRNA)
    d. Transfer RNA (tRNA)
    e. All of the above.

10. Some strain traits are controlled by more than one pair of genes.
    a. True
    b. False

11. Albinism is an inheritable trait for both animals and plants.
    a. True
    b. False

12. The ability to change the inheritance of an offspring is a desirable social goal for mankind.
    a. True
    b. False

GENETICS

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FILMSTRIPS

Basic principles of heredity . . .

INTRODUCING GENETICS

By Richard F. Hunt, Chairman, Biology Dept., Fairport Central School, Fairport, N.Y.

The data and concepts that form the basic principles of genetics are carefully introduced and logically developed in this set of color filmstrips, which also offers opportunities for the exercise of scientific reasoning. The filmstrips are:

DOMINANCE. Inherited traits; parental contribution to the characteristics of the offspring; what dominance is; what a hybrid is; possible ways for determining hybridity.
INCOMPLETE DOMINANCE, SEGREGATION, AND PUNNETT SQUARE. Illustrates and defines the terms mentioned, explains the significance of a 1:2:1 phenotype ratio, and how to make and use a Punnett Square.
INDEPENDENT ASSORTMENT AND LINKAGE. Also includes an examination of how many combinations are possible from a dihybrid cross and the significance of the 9:3:3:1 ratio.

GENETICS AND THE CELL. How genetic factors are transmitted, relationship between these factors and chromosomes, identification of factors with genes, process and significance of meiosis.

NEW TRAIT COMBINATIONS AND MUTATIONS. Difference between multiple alleles and multiple genes, polyploidy and nondisjunction; defines mutations and examines what determines whether a genetic variation is helpful or harmful.

POPULATION GENETICS. Genetic concept of a population; the Hardy-Weinburg Law; factors that account for changes in populations; genetically controlled human traits.

DNA-STRUCTURE AND REPLICATION. Importance, structure, and replication of DNA. Sequential presentation of information in small increments facilitates learning.

DNA AND PROTEIN SYNTHESIS. Nature of DNA structure and replication; materials involved in protein synthesis; current explanation of protein synthesis

DNA AND RNA - EVIDENCE FOR STRUCTURE AND FUNCTION. Chronological review of major discoveries and experiments.

Ward's Natural Science Establishment, Inc., Rochester, N. Y. 14603

DNA: A KEY TO LIFE, Color, Life Filmstrip. Time and Life Bldg., Rockefeller Center, N. Y.

MEIOSIS: SEX CELL FORMATION, Encyclopedia Britannica Films (16 min., b&w, color). Illustrates how meiosis produces genetic variation. Includes studies in crossing over.

Supplementary List
FILMS, FILMSTRIPS AND FILMLOOPS

1. DNA: Molecule of Heredity, Encyclopedia Britannica Films (16 min., color). Explains how a trait is inherited.
2. Laws of Heredity, Encyclopedia Britannica Films (16 min., color). Gives a good coverage of basic Mendelian genetics and problem solving related to the theory of probability.
3. Mendel's "Segregation," AIBS Film Series in Modern Biology, McGraw-Hill Book Co., Inc. (28 min., b&w, color). Explains the principle of genetic segregation. Describes Mendel's experiments and shows how experimental crosses are made.
4. Mendel's "Recombination," AIBS Film Series in Modern Biology, McGraw-Hill Book Co., Inc. (28 min., b&w, color). Illustrates recombination of genetic traits in several crosses.
5. The Science of Genetics, AIBS Film Series in Modern Biology, McGraw-Hill Book Co., Inc. (28 min., b&w, color). Explores the scope and purpose of the science of genetics. Identifies DNA as the bridge of heredity.
6. Chromosomes and Sex, AIBS Film Series in Modern Biology, McGraw-Hill Book Co., Inc. (28 min., b&w, color). Discusses sex-lined inheritance, sex determination, sex ratios, human chromosomes, and gynanders in Drosophila, birds and moths. Shows laboratory work on Drosophila.
7. Genes and Chromosomes, AIBS Film Series in Modern Biology, McGraw-Hill Book Co., Inc. (28 min., b&w, color). Discusses evidence for the location of genes on chromosomes, linkage and crossing over, linkage maps, Drosophila salivary gland chromosomes, and the contributions of Sutton, Boveri, Bridges, and Sturtenant to genetics.

Filmloops from Ealing Corp., 2225 Mass. Ave., Cambridge, Mass. 02140

DNA Transformation Experiment (color, 3 min., 40 sec.). In this filmloop the classic biology experiment involving bacterial transformation is demonstrated. All the laboratory steps, involving incubation, controls, mixing, streaking, and so on, are shown. Cartridged Super-8.

Topic Outline

I. Introduction to heredity

II. Concepts of Inheritance

- A. Pre-Mendelian Concepts
    1. Classical Theory
    2. Preformation
    3. Folk Findings
- B. Mendelian Hypotheses
    1. Indirect inheritance
    2. Independent inheritance of determinants
    3. Rediscovery of Mendel's work
    4. Incomplete dominance
    5. Mendelian Inheritance in a population
- C. Nuclear theory of Mendelian inheritance
- D. Chromosomal Theory of inheritance
    1. Cytogenetics
    2. Sex Determination

III. Probability

- A. Laws of Probability
- B. Types of Probability
    1. *A priori*
    2. Empirical
    3. Samplings
- C. Binomial Expansion
- D. Chi-Squared Test

IV. Chromosomal Behavior

- A. Chromosomal Crossing-over
    1. Theory of factor exchange
    2. Sex linkage
- B. Multiple Alleles
- C. Gene Interaction
- D. Epistasis

V. Mutation

A. Mutagens

B. Evolutionary significance of Mutations

C. Mutant Genes in Populations

VI. DNA and Chemical Basis of Heredity

A. DNA

B. DNA - Replication

C. RNA

D. Transcription

E. Translation

VII. Seminars

I. One Gene - one protein theory

II. Genetics and the future generations.

III. Drugs and genetics

ANNOTATED OUTLINE

I. Introduction to Heredity

Specific References: None

Alternate Student Reading Assignment:
Weisz (1967) pp. 745-747
Curtis (1968) pp. 347-352

Approach

In order to stimulate an initial interest in heredity, one might utilize existing student concepts--whether erroneous or correct--as a springboard into this subject area. Therefore, in order to highlight the relevancy of this topic, one could request that students develop heredity charts regarding their own families and themselves (p. 5-10). Students should be permitted to take the chart home in order that they might have an opportunity to better complete it.

The completed chart should be used in such a way as to lead smoothly into a discussion of specific characteristics and their variations.

From a discussion of specific variations of those traits, a definition of heredity should evolve. Also, from the discussion, a distinction should be made between inheritable and non-inheritable characteristics.

1. Some explanations of heritable characteristics.

    A. Characteristics of organisms which are passed from parent to offspring over successive generations are heritable.

    B. Characteristics of an organism which are acquired as a result of the influence of the environment upon somatic cells (the organism) are defined as non-inheritable; i.e., acquired characters are non-heritable; e.g., walking style.

    C. Characteristics of an organism are studied in terms of their similarities, dissimilarities or variations from one generation to the next.

Alternate Approach

Human beings offer a wide variety of characteristics for analysis. It is one thing to say: "That is a man, a goat, a lion, etc."; but the students should be made to answer questions about what constitutes a man; i.e., what are the features or characteristics that differentiate man from other animals. Once this basic understanding of characteristics of man or other animals has been established, then the class can discuss the variations in them within a given population; i.e., the class. At this point the teacher should select a student's chart for class discussion to see which characteristics are present in his immediate family, and his grandparent's family. The word phenotype can now be introduced and its meaning discussed; i.e., the phenotype is what we see. Do not mention anything about genes as this will only act to confuse the stepladder approach.

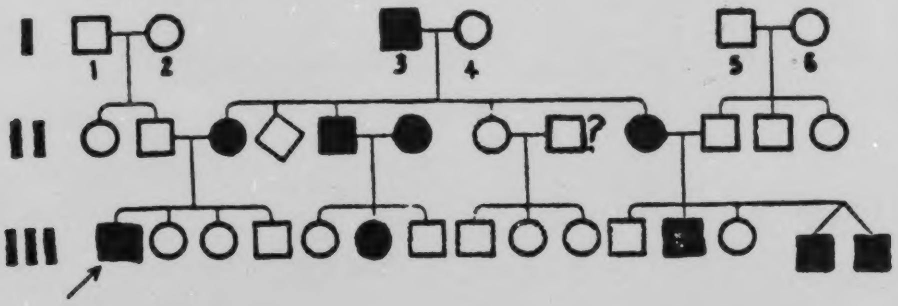
USE THE FOLLOWING CHART TO RECORD YOUR CHARACTERISTICS AND COMPARE THEM WITH INDIVIDUALS IN YOUR FAMILY

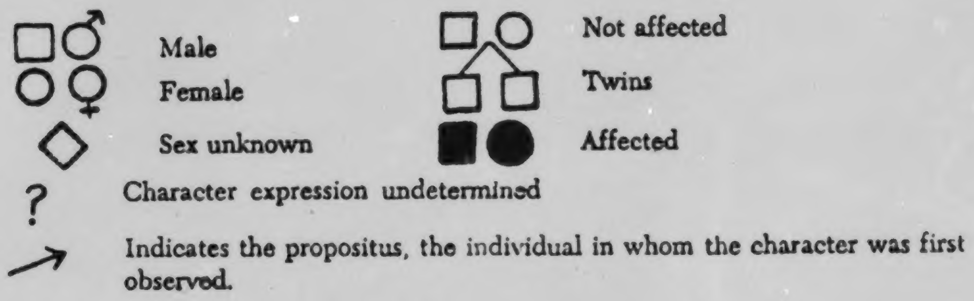
Traits	Your Characteristics	Brother	Sister	Mother	Father	Mother's Father	Mother's Mother	Father's Father	Father's Mother
Eye Color									
Handedness									
Hair Type									
Dimples									
Tongue-rolling									
Ear-lobes									
Fatness									

Hair type - straight, wavy, curly, kinky; brown, black, blonde, red.
Height - short, tall, average.
Eye color - brown, hazel, black, blue, green, gray.
Fatness - lean, medium, obese.
Handedness - right or left.
Tongue-rolling - yes, no.
Dimples - present, absent.

Using the data from the take home chart, construct one or more pedigree charts. This information can be utilized to give clues to the mode of inheritance.

Designate each individual in the pedigree by his generation number (Roman numerals) and his order number in that generation (Arabic numerals) I-2 is the second person in the first generation of the pedigree. A horizontal line between a man and a woman indicates mating. Children of the parents are represented at the ends of vertical lines attached to a horizontal one below the mating line and connected to it by another vertical one. As shown in the accompanying example.


I
1
2
3
4
5
6
II
?
III


Male
Female
Sex unknown
Not affected
Twins
Affected
?
Character expression undetermined
Indicates the propositus, the individual in whom the character was first observed.

Instructor's guide to characteristics listed in the chart.

Eye color. Brown eye color is dominant over blue or gray eye color. Also, hazel and green eye colors are dominant over blue and gray. Let A = brown, A^1 = hazel and green, and a = blue or gray.

Handedness. Right-handedness (Q) is often dominant over left-handedness (q).

Hair type. Curley hair (CC) is not completely dominant over straight hair (C^1C^1). The heterozygous condition (CC^1) is wavy.

Dimples. Present in one cheek, or in both cheeks, is a dominant trait. Dimples (D) are dominant over no dimples (d).

Tongue rolling. The ability to roll the tongue into a longitudinal U-shaped trough (R) is dominant over the lack of this ability (r).

Ear lobes. Free or pendulous ear lobes (G) are dominant to attached or non-pendulous (g) ones.

II. Concepts of Inheritance

A. Pre-Mendelian Concepts

Specific Reading:
Winchester, A. M., 1966. Chapters 1 and 2
McKusick, Victor A., 1969. pp. 1-6
Gabriel, M. and Fogel, S., 1955. pp. 228-233

Do Exercise 29 before starting this section.

1. Classical theory of direct inheritance

   a. Hippocrates (ca. 400 B.C.) claimed that reproductive material originates from all parts of one's body and, therefore, characters are handed down directly.

   b. Aristotle (ca. 350) questions Hippocrates' view because characters like nails, hair, voice, way of moving, etc., don't contribute to reproduction. What is common to these things listed? Things that are not present at birth like gray hair, etc. cannot be accounted for by Hippocrates' view. Another objection deals with plants; a plant with parts missing can produce a whole offspring. Where do the parts present in the offspring and absent in the parent come from? He reasoned that if each parent contributes a part then the offspring must have two parts. Why then do they have only one?

   His hypothesis was that reproductive materials are made up of nutrient substances which, while on their way to various parts, were diverted to the reproductive part. He believed that the male performs a minor role in contributing to the offspring.

However, both men share the notion that inheritance is direct. That is, substances derived directly from or intended (destined) for specific parts of the individual are diverted and transferred to the progeny.

2. Preformation

The Preformationists originated before Aristotle. They contended that the ovum contains within, or, in its substance, a somewhat perfect minature of the adult animal, whose development into an adult consists of its growth and unfolding. They called the minature organism the "Homunculus" in the case of man. This would mean that everybody today existed as individual miniatures from the time of the first female (Eve?).

This view of the woman playing the dominant role was challenged when Anthony van Leeuwenhoek (1632-1723) discovered the spermatozoa and called them animaculae. After the importance of the role spermatozoan plays in fertilization was discovered, a sharp division in the homunculus theory was created because some claimed homunculi were in the ovum while others said they were in the spermatozoan. A microscopist, Hartsoeker, drew human spermatozoa containing a homunculus.

We now know that specific parts of an unfertilized egg eventually differentiate and develop into specific parts of the body--under normal circumstances. This does not imply that the sperm does not contribute anything. (See Unit 4).

3. Folk Findings

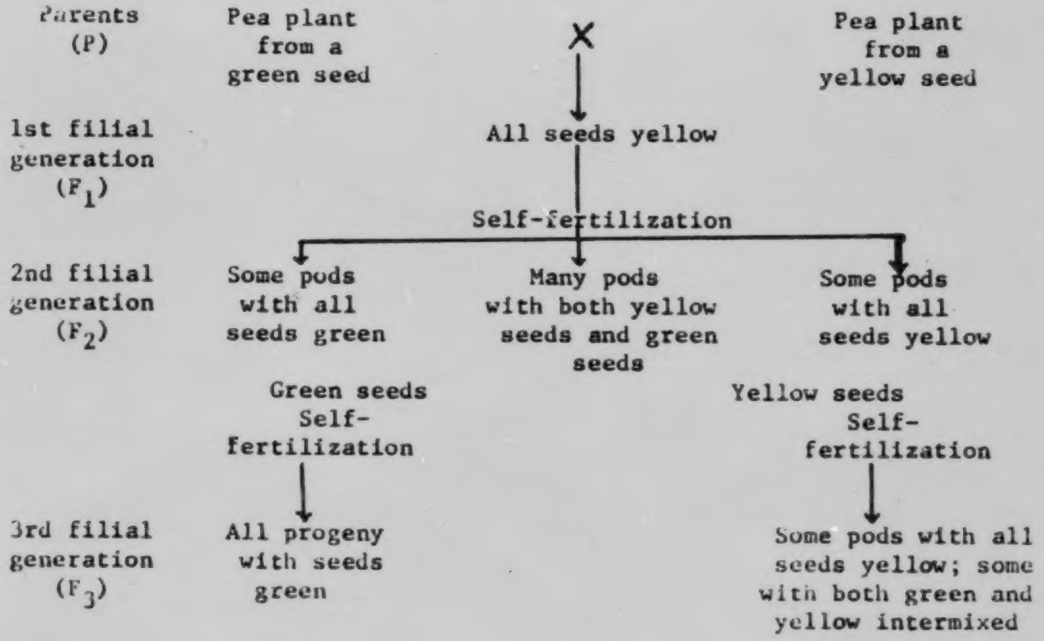
A series of crossing of various species of plants and animals was performed during the 18th and 19th centuries. Nobody challenged the direct inheritance theory of Hippocrates, though their results did not support it. Except for Mendel's theory no alternative hypotheses were expounded.

a. Knight (1799) crossed peas, but did not keep records of his crosses as Mendel did. He established that reciprocal crosses gave identical results, thus, a tall variety of pea pollinated by a dwarf variety and vice versa gave the same result.

b. Goss (1824) went further than Knight. He pollinated green peas with yellow-seeded peas and got all yellow offspring. He planted these F_1 peas the following year and selfed them. They produced all green, yellow, and others with combinations of yellow seeds and green seeds in the same pods of the F_2 generation. He continued selfing these pods. The green produced only green while the yellow seeds produced both green and yellow peas intermixed. He did not count the number of peas in each category.

The characters (presence of pigment) that Goss chose to work with enabled us to say that the green seed is recessive to yellow because, when they were crossed, only the yellow showed in the first generation.

Goss' results from crossing green and yellow peas (Pisum sativum)


Parents (P)
Pea plant from a green seed
X
Pea plant from a yellow seed
1st filial generation (F_1)
All seeds yellow
Self-fertilization
2nd filial generation (F_2)
Some pods with all seeds green
Many pods with both yellow seeds and green seeds
Some pods with all seeds yellow
Green seeds Self-fertilization
Yellow seeds Self-fertilization
3rd filial generation (F_3)
All progeny with seeds green
Some pods with all seeds yellow; some with both green and yellow intermixed

Goss' results from crossing green and yellow peas (Pisum sativum).

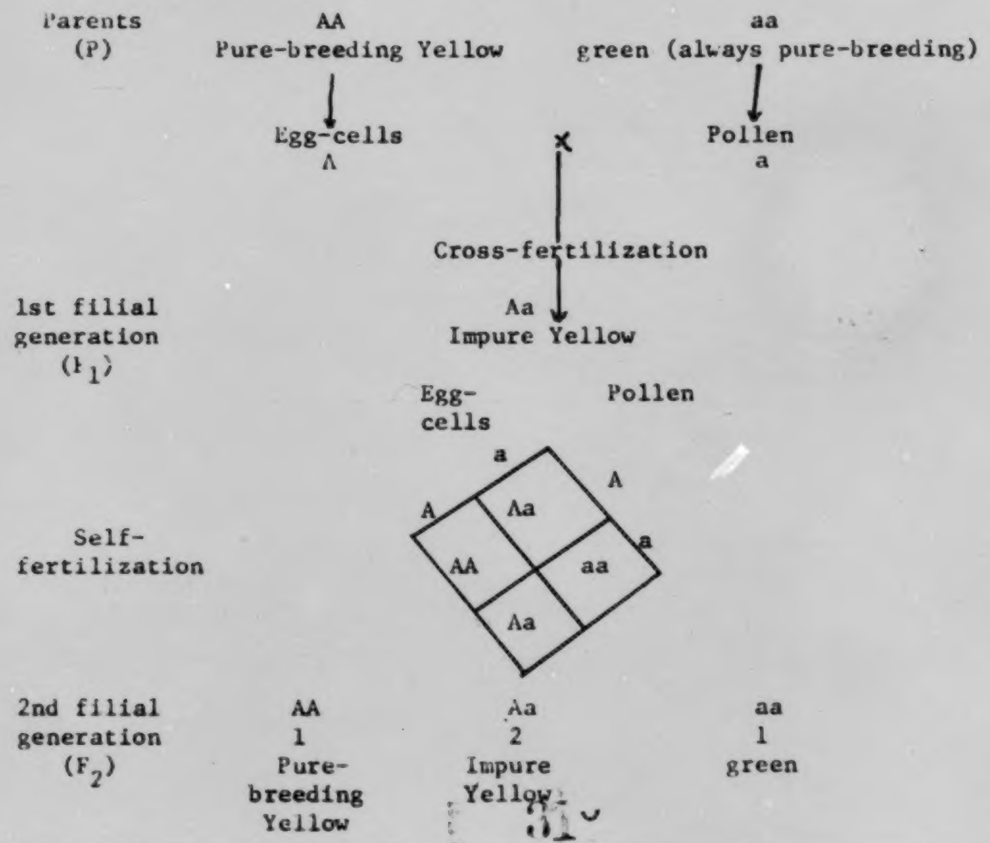
B. Mendelian Hypotheses

1. Indirect Inheritance Hypothesis

Although Mendel's work was done by 1866, nobody challenged the direct inheritance theory until Weismann's (1883) theory of germ-plasm. Darwin (1875) restated Hippocrates' theory. However, he said granules thrown off each part and stored in the individual were responsible for the hereditary transmission.

Mendel differed from Goss and Knight because he recorded his data (observations); i.e., the numbers of progeny of each kind; his work was similar to Knight's. Mendel's interpretation of his data led him to the formulation of theories on purely statistical basis. He introduced symbols like (A) for dominant characters and small (a) for the recessive characters. This implies that there is something that represents or stands for characters; i.e, factors responsible for showing characters. These "factors" should not be confused with the classical view discussed earlier. The implication here is that characters are not passed on (transmitted) directly from parent to offspring but are passed indirectly via discrete particles responsible for the appearance of those characters.

From our knowledge of meiosis and reproduction we know sexual reproduction involves union of two gametes that were independent of each other and came from different sources. Thus, the offspring will receive a particle for a specific character from each parent and will, therefore, have two particles for each character (as in Goss' F_1 generation) which, though it is yellow in color, can produce green offspring.


Parents (P)
AA
Pure-breeding Yellow
aa
green (always pure-breeding)
Egg-cells
A
×
Pollen
a
Cross-fertilization
1st filial generation (F_1)
Aa
Impure Yellow
Egg-cells
Pollen
a
A
A
a
Aa
AA
aa
Aa
Self-fertilization
2nd filial generation (F_2)
AA
1
Pure-breeding Yellow
Aa
2
Impure Yellow
aa
1
green

2. Independent Inheritance of Determinants

To account for his results of crossing two characters Mendel postulated that when two character differences are present each is inherited independently. He assumed that at pollen formation in F_1 plants, pollen grains with four possible combinations of two pairs of factors would arise with equal frequency. He thought the eggs would be formed in similar fashions and that fertilization would be random. This fits his data of 9:3:3:1. (2nd Law)

3. Rediscovery of Mendel's Work

De Vries (1900), Correns (1900), and von Tschermak (1900), independently made experiments similar to those of Mendel and obtained similar results. Correns then introduced "Mendel's Regal" (Mendel's Law) for the basic principle of the separation or segregation during the formation of the reproductive cells of the discrete particulate determinants of alternative characters and their reassociation on fertilization.

4. Incomplete Dominance

Bateson, Saunders and Punnett (1905) found one of the first evidences of incomplete dominance in Mendelian inheritance in which the heterozygote (gray) is an intermediate between the two parental homozygotes (black and white) in domestic chickens (Gallus domesticus). This establishes that dominance is not an essential part of Mendel's theory of heredity. They also found coupling of two characters, i.e., they are linked. Later Doncaster and Traymore discovered sex linkage in Magpie moths.

In order to detect a linkage between two pairs of characters, it is essential to have an individual heterozygous for both character differences to provide the four possible kinds of gamete. Morgan found the white eye to be sex-linked in fruit flies.

Approach

A comprehensive look at the charts supplied by the students should lead to an understanding of dominance, recessive, phenotype and variation of a character. These terms are essential for the understanding of heredity. Instead of assigning Mendel's paper for reading, the students should be asked to name other features; e.g., style of walking (see earlier section) that vary with the individual; i.e., those characteristics of life that are non-heritable.

At this stage an understanding of the differences between what is heritable (inherited things) and those that are acquired or non-heritable should be clear. The students should think and give reasons if colors, as in flowers, seeds (e.g., beans red, white, black eye), etc., are heritable or non-heritable.

How do we inherit characters? Some of the answers to this question will be similar to some folklore or some of past philosophers' view point. Among these will be:

a. Folk stories:

Biblical story of Adam and his seeds, maternal impression (i.e., all a woman needs to do is think of somebody and her baby will look like the person, etc.). Another folk view is the mixing of blood; e.g., he is of Indian or Irish blood. He has bad blood. There is an implication here that blood is the medium of inheritance, etc.

b. Preformation:

Some people used to think that the man or woman plays the dominant role.

Hippocrates', Aristotle's and Darwin's views are different explanations of direct inheritance and are well-discussed in Winchester's book.

The students should be induced to give logical reasons why these theories of direct inheritance are weak. Hint: Unit 1 stresses that a fact must be testable, but none of the above are based on experiments nor are there any proofs for them. They, also do not apply to plants.

Knight's experiments in horticulture should be used at this point. He crossed two beans, yellow and green. Having done reproduction and meiosis, the teacher can ask the students to briefly explain the process of fertilization or pollination in plants. Knight did the same thing but got only one color in his F_1 (yellow) a heterozygote (because the green is recessive to yellow).

Discussion Questions:

1. Discuss the basic differences in the theories of direct inheritance of a character.

2. What contributions were made by the following to our understanding of inheritance: Hippocrates, Darwin, Knight?

3. Contrast the following:

   a. Dominants and recessive
   b. Monohybrid and dihybrid
   c. Acquired and inherited characters

4. Discuss the reasons why all pre-Mendelian attempts to explain inheritance were futile.

5. Discuss the probable factors that prevented Mendel's work from being well disseminated before its rediscovery in 1900.

C. Nuclear Theory of Mendelian Inheritance

In his germ plasm theory Weismann insisted that the chemicals inherited could not be modified during the lifetime of the organism. He, thus, destroyed the inheritance of acquired characters. Hertwig and Staburger contributed to Weismann's postulation by claiming that heredity is based on the transmission of nuclear substance with a specific molecular constitution. Boveri's cytological observations (1889) lent strong support to the theory that the nucleus is the carrier of hereditary material. He claimed that the egg nucleus in echinoderms is essentially like the sperm nucleus in hereditary contribution and that the maternal cytoplasm has no influence on the hereditary material.

Experiments utilizing graftings of different species of Acetabularia showed that the nucleus located in the shizoid has an over-riding control over the formation of the type of cap. The length of the stalk also seems to influence the cap formation since it was found that the cap type also depended on the length of the stalk grafted to the shizoid. This, however, does not negate the fact that the nucleus has overall control. Enucleated eggs do not develop, but once a nucleus is transplanted into them, their development can begin again. This decreases the importance of the role of cytoplasm in heredity.

D. Chromosomal Theory of Inheritance

Do Exercise 16. (Chromosome squash preparations)

1. Cytogenetics

Beneden (1883) noticed that both the egg and the sperm contained equal numbers of chromosome and during mitoses in fertilized eggs the number of chromosomes are double its original number. He thus established that gametes are haploid and that zygotes are diploid. (Review meiosis here.)

Montgomery (1901) studying insects observed regular formation of pairs of the chromosomes even though the haploid chromosome number is odd. This led him to conclude that bivalent associations at prophase 1 are always made up of one paternal and one corresponding maternal chromosome. Sutton was able to identify individual chromosomes by size and confirmed Montgomery's findings. Boveri's experiments on sea urchin strengthened their view.

In 1903 Sutton formulated the chromosome theory of Mendelian heredity based on his work as well as those of Boveri and Montgomery. He noticed the resemblance between the separation of homologous chromosomes at meiosis and Mendel's postulated separation of character differences at gamete formation. The homologous chromosomes align independently at metaphase 1. This can lead to a number of maternal and paternal combinations that are different from each other in the gamete nuclei.

2. Sex Determination

Wilson in 1905 discovered the single X chromosome in males that has two counterparts in females. He concluded that sperms that receive the X chromosome give rise to females and those that don't result in males. He termed the male chromosomes XY and XX for females. He argued that Y chromosome plays no part in sex determination. On the basis of this theory Morgan postulated the white eye characters of his fly are carried on the X chromosome, thus laying down the theory of sex-linkage. Bridge's finding that XXY individuals are females seemed to confirm Wilson's theory that the amount of X chromosomes present is what determines the sex of an organism. Later it was shown that maleness is carried not on the Y chromosome but on sets of autosomes. The Y is a nearly-empty X chromosome that is needed for fertility in males. Let A = a set of autosomes. Then:

	Ratio of X:A
AAXX = female	1.0
AAX = sterile male	.5
AAXY = normal male	.5
AAXXX = superfemale	1.5
AAAXX = intersex	.67
AAAXY = supermale	.33

Discussion Questions on Sex Determination:

1. What proportion of the human progeny receive an X chromosome from the father? What proportion receive an X chromosome from the mother? What proportion receive an X chromosome from the mother and a Y chromosome from the father?

2. What accounts for a Y chromosome from a father producing a male and an X chromosome from the same father producing a female?

3. What must be the relationship between the X and Y chromosomes in producing sexuality?

4. When does sex determination take place in human beings?

5. Is sex determination genetic in all organisms?

6. What other factors influence sex?

7. How is sex determination in human beings different from that in the fruit fly?

E. Autonomous-Structures

While Mendelian inheritance is the rule, it is known not to be universal. Correns (1909) found a different kind of inheritance in some plants. The ratio of different offsprings from his crosses were highly variable. Notably, his plants showed maternal inheritance and also yielded divergent results from their reciprocal crosses. Some structures, like plastids, are known not to be under control of the cell nucleus and exist as autonomous self-replicating structures within the cell. These structures are characterized by a lack of regular segregation of character differences, variable progeny ratios, and maternal inheritance.

III. Laws of Probability

Specific References:

Adler, Irving (1963), pp. 1-256
David, R. P. and L. H. Synder (1957)
Gardner, E. J. (1960), Ch. 3, pp. 40-52
Harrison, D. (1970)
Winchester, A. M. (1966), Ch. 7, pp. 100-114

The need for the theory of probability is a consequence of man's yearning or desire to predict the events around him or to arm himself with a means of appraising the various courses of action in the face of uncertainty. The theory of probability, as it turns out, is one of the most powerful tools in genetics. All of the basic tenets of genetics, particularly Mendelian genetics, are by their nature statements of probability. Thus, Mendel's work simply means that the probability of obtaining a plant with yellow seeds from crossing two hybrids (yellow and green) is three times out of four.

Basic to the theory of probability are the assumptions that it is something measurable on a continuous scale, and that it can be expressed as a real number.

A. Probability laws

Whenever there is a large number of events one can reasonably predict the number of these events which will be of one sort or the other by use of the probability laws.

1. One law states that the chance of the simultaneous occurrence of two independent events is equal to the product of their separate occurrences.
2. The other states that the chance of one or the other of two mutually exclusive events occurring is the sum of their separate probabilities.

B. Types of probabilities

1. A priori probability is one which can be stated in advance because of the nature of the event. Example: Throwing a die. The chance that anyone side comes up is one in six or 1/6.
2. An empirical probability is obtained by counting the number of times a given event occurs in a certain number of trials. The number of albino corn seedlings in a given population of a cross of corn hybrids (Exercise 29 is an example).
3. A sampling probability is one in which data is collected about a particular event and then used comparatively with an expected ratio.

C. The binomial expansion theorem is a statementof a mathematical process that can be used for rapid computation of probabilities. It consists of the expansion of a binomial such as $(a+b)^n$.

D. Chi-squared Test

In many instances, events may occur which do not coincide with the expected numberof occurrences based on a priori probability. It then may be important to determine how much variation from the nubmer expected can be attributed to chance alone. A statistical tool, Chi-squared can be used to determine "goodness of fit" of the results obtained. (Use data from Exercise 29.)

Probability: An approach.

It is desirable that the instructor begin this topic by making an introductory statement explaining the meaning of probability. The following illustration may be utilized to introduce the laws of probability: In the desk drawer or some other container are placed several objects of different colors. Example: 2 green, 4 red, 6 blue objects. Ask students to predict the chance of picking a single green object from the container. The chance, of course, is 2/12 or 1/6 since there are 12 objects and two are green.

To introduce binomial expansion the following assignment should be made a day in advance of the discussion period. Have students organize into groups of five or more with one student serving as spokesman for the group. Have each group call a local hospital (if there is more than one in the town) and find out how many babies were born on a certain day and the sexes of these babies. Compute by use of binomial expansion how often this proportion of boys should occur to girls and then how often all should be girls (boys). Chi-squared can then be used to show if discrepancies encountered can be reasonably ascribed to chance alone. The Chi-squared test should be explained and Chi-squared computation charts for 3:1 and 9:3:3:1 expectations should be mimeographed and given to each student.

IV. Chromosomal Behavior

A. Chromosomal Crossing Over

References:

Bonner and Mills (1968), pp. 20-24; 71-78; 86
Kemp, Roger (1970)
Levine (1968), pp. 79-112
Ohno, S., Sex Chromosomes and Sex-Linked Genes (1967), Springer-Verlag, N. Y.
Roberts, J. A. Frazer (1967), pp. 136-143

1. Theory of Factor Exchange

Sutton indicated, in formulating the chromosome theory of Mendelian heredity (see Gabriel & Fogel, pp. 248-254), that the number of distinct characters in an organism must exceed the number of its chromosomes. He then reasoned that an allele was only a part of a chromosome, and that, if the chromosomes permanently retain their individuality, all the factors representing one chromosome must be inherited together. However, some independently inherited character differences, aside from those of Mendel's, were found, thus contradicting the chromosome theory.

If the chromosome theory cannot explain independently-inherited characters, then what causes these characters to be independently inherited? To answer this question, review meiosis again with the class. Only this time let the students use modeling clay instead of pipe cleaners, so they can observe and produce breakages in chromosomes.

De Vries accepted Sutton's view that chromosomes formed the basis for Mendelian heredity, and that many factors must exist together. To resolve the problem of independently-inherited characters, he postulated that an exchange of materials occurred between the maternal and paternal homologous chromosomes. (Explain the meaning of homologous, and review prophase 1 of meiosis in detail.) This exchange is based on change because the point of breakage, when the chromosomes are being pulled to the poles, can occur at any point along the entire length of the chromosome. De Vries reasoned that a factor can only be exchanged for one like it, i.e., "A" for "a." Thus, after the exchange, each chromosome will contain some paternal and maternal parts (or units). Since the two chromosomes pass into different gametic nuclei during anaphase of meiosis II, the redistribution of factors between homologous chromosome pairs will lead to gametes with a variety of combinations of the father's character differences as required by Mendel's theory.

2. Sex Linkage

From the above it is safe to argue that characters whose factors are very close together on the chromosome will most likely be transmitted together. In the case of sex-linkage there is only one X chromosome and the factors will, therefore, not be crossed over because the Y chromosome is almost empty of genes. Thus, in F_1 the sex-linked (factors) characters will appear in the male if they are on the X chromosome.

One of the assumptions here is that the factors are located on the chromosomes because of the close correlation between chromosome behavior during meiosis and Mendel's experiment. Suppose we now call Mendel's particulates genes, then the factors are the genes and we can, therefore, assume that they are located on the chromosomes.

In discussing sex linkage, one must allude to the classic examples of sex-linked features such as pattern baldness, color blindness and royal hemophilia. A consideration of at least one family pedigree in which there is such a sex-linked feature can provide the basis for constructive discussion. The Ishihara test for one kind of color blindness, the familiar "red-green" color blindness, can be used to determine whether it exists among members of the class and their families. About 8 per cent of males and 0.5 per cent of females show this trait, which has been traced to the X chromosome.

Approach

Before showing any filmloops or filmstrips on linkage or independent assortment, the teacher should take the class through a thorough revision of the meiotic process and induce the students to master definitions of parts like centromere, chromatid, allele, chiasma, centrosomes, etc. The discussion of the meiotic process should not be a mere recitiation of the stages of meiosis but, a discussion that will involve why breakage will probably not occur near the point on the chromosomes (the centromere) that is being pulled toward the poles--the consequences of the chromosomes lining up at the equator during metaphase, and the pulling at the centromere during anaphase 1. This will generate the idea of genetic crossing-over being a consequence of random breakage and random reassociation of the homologous chromosome.

The teacher should demonstrate crossing-over in living organisms by crossing fruit flies of different phenotypes, as shown in Demerec and Kaufmann (1961).

The aim of this approach is to help establish in the mind of the student a correlation between the behavior of factors in Mendel's experiments and chromosome behavior. At this point the reading assignments should be discussed in conjunction with observations of filmloops.

Since a correlation has now been established between the behavior of the factors and chromosome movements during meiosis, the students should be able to conclude that the factors or genes are probably located in the chromosomes. To help facilitate the students inference, do Exercises 15 and 16 with emphasis on chromosome bands. A change in band patterns indicates cross over, deletion or translocation.

Discuss the implications of what happens when a fragment of chromosome breaks up and did not attach to another chromosome, or when this broken piece is attached to another chromosome without a reciprocal loss in the recipient. For details on the consequences of this type of translocation in humans see McKussick's Human Genetics.

Questions like why a color blind father doesn't pass the gene for color blindness to his sons should be addressed to the students to induce them to master the concept behind it. In cases where sex-linked features are noted, the teacher should capitalize on the inherent relevancy of this trait by encouraging discussion and the desire to look at the subject in greater depth with the object of understanding it.

A set of 13 two-by-two color slides for testing color blindness can be obtained from General Biological Supply, Rochester, N. Y., or refer to the color chart on p. 97 in L. H. Snyder and P. R. David, The Principles of Heredity, 5 ed., Heath, Boston, 1957. Other tests for color blindness are the Holmgren test, which makes use of dyed yarn skeins and the Ishahara test book from which the above slides are photographed.

Self-Test on Linkage and Crossing Over

Multiple Choice:

1. Which of the following types of sex determination is prevalent in mammals including man:

   a. XY type
   b. XO type
   c. ZW type
   d. male haploid type
   e. none of the above

2. Consider the following data concerning cross over frequency, then choose the statement that seems warranted on the basis of this data.

   Frequency of crossing over between A and B = 10%
   Frequency of crossing over between B and C = 2%
   Frequency of crossing over between C and D = 8%
   Frequency of crossing over between D and E = 6%
   Frequency of crossing over between C and E = 2%

   a. The genes A, B, C, D, and E are arranged in linear order and are equally spaced on the chromosome.
   b. Gene E lies between C and D and is closer to C than to D.
   c. Gene E lies between C and D and is closer to D than to C.
   d. Cross over frequencies are of no value in mapping chromosomes.
   e. The genes A, B, C, D, and E are arranged in the following order: A, D, E, C and B; A and B are the most distant loci on the chromosome.

3. The number of linkage groups that can be determined for a species corresponds to:

   a. the number of genes present in the germ cells.
   b. the diploid number of chromosomes present in germ cells.
   c. the haploid number of chromosomes characteristic of the species.
   d. the number of sex chromosomes.
   e. none of the above.

4. Linkage and crossing over are phenomena that provide important proof for:

   a. the theory of inheritance of acquired characteristics.
   b. the Mendelian law of heredity.

c. the chromosome theory of heredity.
d. the theory of blending inheritance.

True-False:

5. The inheritance pattern of the ebony-body trait strongly suggest that this characteristic is linked.

6. The absence of any ebony-bodied, hairy flies in the F_2 generation tends to indicate that the two pairs of alleles under consideration are linked.

7. The phenotypic ratio in the F_2 generation seems roughtly normal for that expected from a typical dihybrid cross involving nonlinked gene pairs.

Questions on Sex-Linkage:

8. If a healthy man marries a woman who is a hemophiliac, is it possible for them to have normal children? What would you say about sex of the normal offspring resulting from this marriage?

9. If a color blind man married a normal, healthy woman whose father was color blind, could they have a son with normal vision? Could they have a color blind daughter?

10. A man and his wife both have normal vision, but their first child is born color blind. What are the chances that the next child will be a color blind daughter? What are the genotypes of the parents of the man and his wife?

11. In man, migraine (a type of headache) is due to a dominant gene. A woman who has normal vision and does not suffer from migraine takes her daughter to a doctor for a check-up. During the examination, the doctor finds his patient to be suffering from both migraine and color blindness. What can he immediately infer about her father?

12. What is the proof that the gene for color blindness is not found on the Y chromosome?

B. Multiple Alleles

Do Exercise 31 before beginning this discussion.

There are homozygote characters that show Mendelian modes of inheritance (e.g., albino coat color for mice) from which we can obtain more than two alternatives. This can be demonstrated by crossing the different strains of albino mice. Cuenol (1904) performed this type of breeding and got some offsprings with black coat color and others with yellow coats.

albino x albino
black , yellow

He crossed these offsprings with the wild type (i.e., mice of gray color). The black-gray cross showed the black color to be inherited as a Mendelian recessive character while the yellow was dominant in its mode of inheritance. A continuation of the crosses showed the colors behaving as though they are alleles to one another, i.e., the characters for coat colors behaved like a series of alleles. Other multiple alleles exist in corn (Zea mays) affecting the color of the seeds. However, one of the best examples of multiple alleles is to be found in the white eye mutant of Drosophila melanogaster (fruit fly), for which over a dozen alleles are now known. Allelic mutants when in series have two distinct characteristics:

1. The alleles affect the same character, e.g., coat color, eye color, etc. and are non-complimentary. This means that when two of these alleles are crossed the F_1 generation is either an intermediate between the two or it is like one of them, while non-allelic mutants, though they may affect the same character, can usually compliment each other. This is to say that each non-allelic mutant carries the dominant allele of the other recessive character and, so the F_1 will look like phenotypically normal organisms (the wild type).

2. Allelic mutants don't show recombinations with one another when crossed, but more importantly, they each give the same recombination frequencies with other mutants. Non-allelic mutants show recombinations with one another when crossed giving some normal (wild) type and some double - mutant individuals and parental ditypes. The recombination frequencies of non-allelics also differ from one another. When confronted with the above observations, the logical conclusion can only be that all those alleles occupy the same spot (area) on the chromosome, while non-allelic mutants occupy different spots whether on the same or different chromosome.

Approach:

I. Strain A (albino) x Strain B (albino)
↓
Yellow, Black

II. Yellow x Gray (wild type)
↓
All Yellow [Yellow dominant to gray]

Yellow x Black
↓
Yellow and Yellowish Gray

Black x Gray
↓
All gray [Gray dominant to yellow]

The above can be presented as a problem for discussion in the class and through logical reasoning followed step by step to the conclusion. The observations and reasoning must be compared at every level with the observations and reasonings of Mendel's findings.

Having solved this problem, the teacher should then proceed to discuss Exercise 29 which should be done before discussing multiple alleles. Blood is one of the best examples of a character found in man that demonstrates multiple alleles. Problems on this topic are listed in the laboratory manual (Exercise 29) and in standard texts (See Reference List) for the teacher to choose from for students to discuss in class and for homework.

C. Gene Interaction

References:

Gardner, E. J., 1960. Chap. 5, pp. 79-97

Do Exercise 3 before beginning or during this disucssion.

We have, so far, dealt with the behaviors of factors (genes) and chromosomes and, based on logical reasonings from cytological evidences, concluded that the genes are probably located somewhere on the chromosomes.

However, we have been assuming up till now that one gene or factor (and its allele) affects one character, while evidences have accumulated to show that some of our phenotypic observations are affected by more than one gene. The eye color in fruit fly is a classic example of this type of behavior of the genes. There are human beings with green, brown, blue, hazel, etc. eyes. This may not be the result of the action of one gene, as far as we know at this point. Fruit flies have red, cinnabar, brown, vermillion, scarlet, eosin, white, etc. eye colors. However, it is possible to produce brown-eyed flies with either vermillion, cinnabar, or scarlet pigment also. The flies will have either $\frac{bw\ cn}{bw\ cn}$, $\frac{bw\ st}{bw\ st}$ or $\frac{bw\ V}{bw\ V}$ genetic composition. This indicates that when the phenotypic product of the gene responsible for brown is mixed with the phenotypic product of one of the genes responsible for the other three colors the result is different from either of the two pure products.

Examples.

1. Purple color in flowers of sweet peas occurs only when both the dominant allele for a gene (C) and the dominant allele for another gene (P) are present together. In the absence of either dominant allele, the flowers are white. A dihyhrid cross involving these characters can be summarized as follows:

P   CCPP purple   x   ccpp white

F_1 CcPp purple   x   CcPp purple

F_2 9 C-P- purple   3 C-pp white   3 ccP- white   1 ccpp white

C regulates the production of a necessary raw material for the anthocyanin pigment, and P regulates the conversion of this raw material into anthocyanin.

2. In guinea pigs the gene for production of melanin has the effect of masking the phenotypic expression of the gene for deposition of melanin. The first gene has two alleles: C, which causes the pigment to be produced, and c, which causes no pigment to be produced; hence, a homozygous recessive individual, cc, is an albino. The second gene has an allele B that causes

deposition of such melanin, giving the guinea pig a black coat, and an allele b that causes deposition of only a moderate amount of melanin, giving the guinea pig a brown coat. Neither B nor b can cause deposition of melanin if C is not present to make the melanin. We can summarize a cross involving these two genes as follows:

P		CCBB black	x	ccbb albino	
F_1		CcBb black	x	CcBb black	
F_2	9 C-B- black	3 C-bb brown		3 ccBb albino	1 ccbb albino

3. Sometimes two different genes influencing the same character interact to produce single-character phenotypes which neither gene alone could produce. One example is the control of the form of the comb in chickens. One gene, R, produces rose comb, while its recessive allele, r, produces single comb. Another gene, P, produces pea comb, while its recessive allele, P, also produces single comb. A cross between a Wyandotte (rose comb) and a Bramma (pea comb) is summarized as follows:

P		RRpp rose	x	rrPP pea	
F_1		RrPp walnut	x	RrPp walnut	
F_2	9 R-P- walnut	3 R-pp rose		3 rrP- pea	1 rrpp single

Note that when R and P occur together, they produce walnut comb, a type of comb that neither could produce alone.

D. Epistasis

The masking of a gene by another gene that is not allelic to it is called epistasis. It is different from the concept of dominance because dominance is the expression of a single gene at the expense of its allele. The example above of the effects the gene for brown eye pigment has on the scarlet, cinnabar, or vermillion is an epistatic effect. Exercise 3 in the laboratory manual can be used to demonstrate the principle of epistasis. Thus, a source of white light is split into its component colors and if one of these colors was removed, e.g., red, the resultant combination of the rest of the colors will not give pure white light.

Demonstration:

Chromatography of gene products.

Since Morgan discovered that the white eye is a mutant form of the red eye in D. melanogaster, the white eye mutant as well as fruit flies in general have played significant roles in formulating concepts in genetics. The white eye locus has been found to contain a series of other eye color alleles (referred to in multiple alleles). Apart from the wild type and white locus there are other loci in the chromosomes that affect eye color. An interaction of the products of the genes for brown, scarlet, and vermillion gives a product, which is phenotypically similar to the pure white eye mutant. If these different mutants are chromatographed using the appropriate solvents, the differences can be perceived visually.

The eye of the wild type fruit fly has seven compounds, known as the pteridines that migrate at different rates when chromatographed. These pteridines represent products of gene activity. The order in which they separate is: drosopterin, isoxanthopterin, xanthopterin, sepiapterin, 2-amino-4hydroxpteridine, biopterin, and isosepiapterin.

Procedure

1. Take a 5 x 7 inch rectangle of Whatman No. 1 filter paper and lightly pencil a line 0.5 inch from one of the 7 inch edges and parallel to it. Lightly mark this line with dots at one inch intervals. Crush two etherized wild type Drosophila of the same sex on the first of these dots, using a glass rod. After the flies have been crushed, wash the glass rod in a solution consisting of equal parts of 28% ammonium hydroxide and n-propanol (propyl alcohol).

2. Repeat step one, using two of each of the mutant flies. Among appropriate mutants are white, scarlet, brown, vermilion, plum, and eosin eye colors. Space the different mutant types at the one inch intervals indicated on the filter paper. Wash the glass rod after each type of fly has been crushed or use a fresh one. With a pencil label each spot to the left by letter or number and record which type of fly was crushed at each location. Allow the spots to dry in air for several minutes before proceeding.

3. Now fold the paper into a cylinder about 2 inches in diameter and 5 inches tall by stapling the five-inch edges together so that they do not overlap.

4. Place approximately 35 to 50 ml. of a solvent mixture consisting of equal parts of 28% ammonium hydroxide and n-propanol into a 1000 ml. beaker and insert the filter paper with the crushed fly spots downward. The solvent should be sufficiently shallow in the beaker so as not to touch the spots where the flies have been crushed. Cover the beaker with a sheet of plastic film (Saran wrap, etc.) and secure this with a rubber band. The filter paper cylinder should not touch the sides of the beaker. The chromatogram should be developed in a darkened cabinet since pteridines are light-sensitive.

5. Allow the chromatogram to develop in the closed beaker for 75 to 90 minutes. During this time the solvent front will approach the upper edge of the cylinder, and in doing so will carry the various pteridine pigments for different distances in the paper, thus separating the pigments from each other in the

paper. Now remove the paper cylinder from the solvent and allow it to air-dry in standing position for several minutes in the dark.

6. Carefully remove the staples and unroll the dry chromatogram. Examine the chromatogram under ultraviolet light in a darkened room or chamber. IT IS IMPERATIVE TO WEAR GLASSES OR GOGGLES WHEN USING ULTRAVIOLET LIGHT [See Teachers Guide to Exercise 6].

The various pteridines, (in order of separation) emit different colors; drosopterin - orange, isoxanthopterin - blue-violet, xanthopterin - green-blue, sepiapterin - yellow, 2-amino-4-hydroxypteridine - blue, biopterin - blue, and isosepiapterin - yellow.

This demonstration can also be assigned as a class experiment.

References:

Hadorn, E., 1962. Fractionating the Fruit Fly. Scientific American 206(4).

Leitenberg, M. and E. Stokes, 1964. Drosophila Melanogaster Chromatography:

Part I, Turtox News 42(9):226-229.

Part II, Turtox News 42(10):258-260.

V. Mutation

Reference:

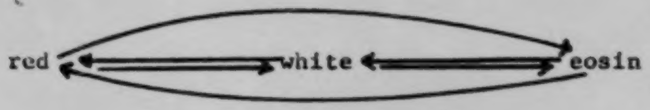
Bonner, D., and S. Mills, 1964. p. 57

Do Exercise 30.

De Vries introduced the term mutation in 1900 to describe what happens when new forms of evening primrose (Oenothera Lamarckiana) that differed appreciably from the original arose in each generation. This also explains the origin of the character differences shown in Mendelian inheritance. Most of the mutations described by early geneticists were expressed as visible changes in morphology of the organism, e.g., eye color. The detection of mutants now ranges to biochemical pathways.

Most mutations were expressed as a recessive, or deficient state that could be detected only in diploid organism when present in combination with a similarly deficient allele. Normal genes are dominant over most of the mutant alleles. This will tend to imply a change in the structure of the gene.

It is possible for some genes to mutate in more than one way. This is implied by multiple alleles. In the white eye all the alleles are reversible as shown.



An important feature of a mutated gene is its replication and transmission to the progeny in the mutated form.

A. Mutagens or Mutation-Producing Factors

1. Muller and his co-workers used ionizing radiations such as X-rays to produce chromosomal breaks. They studied lethal mutations in the X chromosome in fruit flies. Thus, the X-ray produced both visible changes in the chromosome structure and functional changes in a highly correlated manner. Other workers examined the giant salivary gland chromosomes of fruit flies and observed minute deficiencies in chromosomal bands associated with some mutations. These deficiencies were then correlated with map positions of mutant genes on the chromosome.

2. Ultraviolet light was shown to cause mutations perhaps due to its selective absorption by nucleic acids. This suggests that mutation is not only the result of changes in chromosomes but specifically in the nucleic acids present in the chromosomes.

3. A variety of chemicals are known to induce mutations when organisms are exposed to them. Among these chemicals are formaldehyde, mustard

gas in cyclohexane, urethane (ethyl carbamate), hydrogen peroxide, and manganous chloride. They all produced a wide range of mutations with no evidence for specific action on any particular gene.

These different agents were also found to cause chromosomal rearrangements visible under the microscope. The rearrangements include deletions, loops or inversions and translocations. They also establish the gene as a unit of mutation. The fact that a gene may mutate in more than one way as in multiple alleles does not alter the fact that the gene is a functional unit of mutation.

B. Evolutionary Significance of Mutations

Organic evolution is a change in the genetic composition of a population. This change is dependent to a large degree upon sexual recombination, mutation and natural selection. Mutations serve as the raw materials for evolution upon which natural selection acts.

C. Mutant Genes in Populations.

In the study of population genetics one needs to be cognizant of the basic concept of equilibrium. That is the frequency of genotypes produced by a mutant gene and its allele will remain constant in a large population where random mating occurs as in:

a. mutant genes in man
b. bacterial resistance
c. insect resistance

Hardy-Weinberg law will also apply here. (See Section III)

Approach.

Do Exercise 30 from the Laboratory Manual. For further discussion see the Teacher's Guide to the Laboratory Activities.

Discussion Questions:

1. Explain the significance of mutation in evolution.

2. How do mutations become established in a population?

3. What kinds of children, with respect to these blood groups, might be expected from the marriages indicated below.

   O x A   O x AB   A x B   AB x A

4. Discuss the relation between mutation frequency and radiation frequency?

5. Are human males handicapped by a shortage of genes?

6. How and what type of diseases can be inherited?

7. Discuss why more males are color blind than females.

VI. DNA and Chemical Basis of Heredity

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Barish, N., 1965
Crick, F. H. C., 1966, 1962, 1957
Hurwitz, J. and Furth, J., 1962 (Paper)
Levine, R. P., 1968, pp. 173-186
Taylor, J. H., 1958

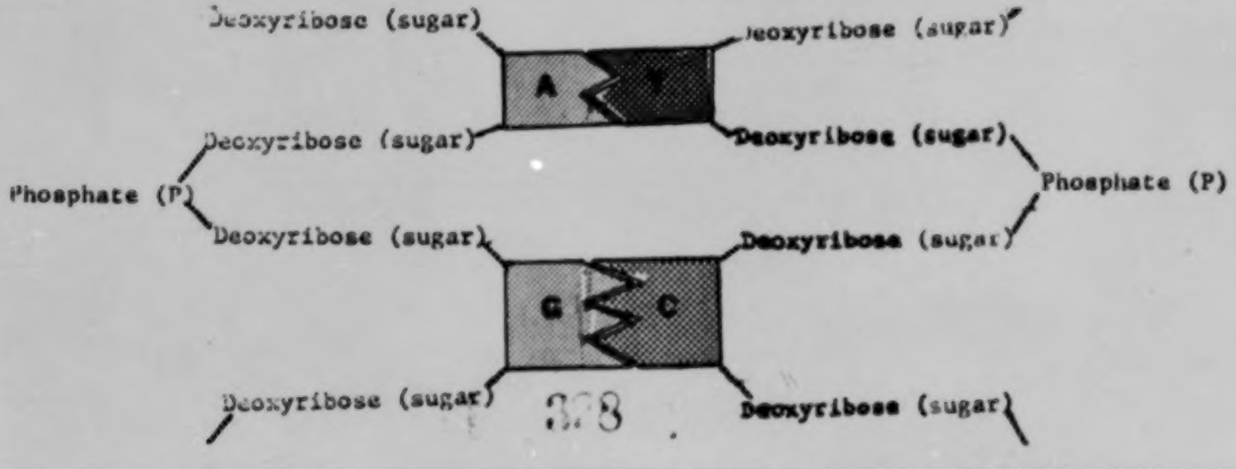
A. DNA

Miescher, 1871, established that the chief constituent of the nucleus is nuclein (nucleoprotein) - a combination of nucleic acid and basic proteins. The nucleic acid in combination with the protein was later found to be DNA. On hydrolysis the DNA yielded purines (adenine and guanine), pyrimidines (cytosine and thymine), phosphoric acid, and a sugar called deoxyribose.

In 1928 Griffith discovered genetic transformation. (see details in Levine or Bonner, pp. 9-11). He used pneumococci to show that cellular extracts of dead bacteria when added to living harmless bacteria could transmit to them, and through them to their progeny their virulent character and their ability to make capsules. This means the cells somehow acquired an hereditary characteristic.

Avery, MacLeod and MacCarthy(1944) found that DNA was the most probable carrier of a specific hereditary character in penumococcus. Hershey and Chase (1952) added additional evidence for DNA being the genetic material by working with bacteriophages. They found that the protein and the DNA of these phages are formed from constituents of the bacterial protoplasm. From experiments involving tagging the DNA with ^{32}P and ^{35}S protein, they concluded that the phage DNA and not the phage protein is necessary for the process of phage reproduction, i.e., the phage DNA carries the genetic material because the protein did not infect the host cell.

Having established that DNA is the most probable and perhaps the carrier of the genetic information, attention was then directed at its structure. It was found that the adenine binds to thymine and guanine to cytosine by hydrogen bonding. DNA was found to consist of a double helix of the polynucleotides because the sugar of guanine is bound to the sugar of thymine by bonds to phosphate.



Similarly adenine is bonded to cytosine. The sugars are bonded to the other nucleotide via another phosphate bonding, thus, forming two chains whose only contracts are at the purine and pyrimidine bases that jot out. These two chains or helices are strung together in opposite directions to facilitate easier hydrogen bondings between a purine on one helix and a pyrimidine on the other helix. Thus, regardless of the source, the DNA will contain equivalent amounts of purines and pyrimidine bases, and also, since A only binds to T and C to G on the helices, quantitatively A must be equal to T, and C equal to G.

The ratio of A + T to G + C may vary from species to species, but is constant for a given species.

It is possible for one species to have more guanine and cytosine bases in their genetic material while another species may have more adenine and thymine.

B. DNA - Replication

Since this genetic material is transmitted to the offspring, it must be capable of replication. (Why?).

The Watson-Click model encompasses a mechanism for DNA replication taking advantage of the complimentary nature of the chains and the base pairing specificity ($G \equiv C$, $A = T$). The mechanism envisaged a separation of the two strands at the hydrogen bonds joining them together. This would then leave the hydrogen bonds free for pairing with new bases, resulting in four strands or two new double helices of DNA. This means that each resulting molecule will be half new and half old. This is the semi-conservative replication. Experiments by Taylor involving incorporation of radioactive thymidine into bean seedlings showed that the radioactive thymidine wound up in the chromosomes where both daughter chromosomes (after duplication) were uniformly labeled. This is the same result that was predicted by the semi-conservative replication hypothesis.

Meselson and Stahl (1958) grew bacteria on a medium containing heavy nitrogen (^{15}N) metabolite for several generations and then added normal nitrogen (^{14}N) metabolite to the medium. Samples were then withdrawn at various intervals and the DNA analysed for weight. By the end of one generation the density of the DNA in that generation was intermediate between DNA of heavy ^{15}N and that of normal ^{14}N, i.e., hybrid DNA has been formed. The dilution of the ^{15}N continued further with successive generations living on the medium containing ^{14}N. This result lends strong support to the semi-conservative replication theory.

Others have since then performed enzymatic synthesis of DNA.

C. RNA

RNA consists of the same purines and pyrimidines as DNA, except for the substitution of uracil for thymine. It differs from DNA is being a single-stranded polymer instead of a double-stranded one, and the sugar is ribose instead of DNA's deoxyribose. It exists, like DNA, in long chains with a phosphate backbone connected by carbons at 3 and 5 positions of the sugar (ribose) as in DNA. The purine to pyrimidine ratio is not 1:1 as in DNA, nor does it give X-ray diffraction patterns like DNA, suggesting that RNA is single- and double-stranded, that is, hydrogen bonding is not a regular feature and therefore, the strands would occasionally bend back forming loops to bond with itself, resulting in A=U and G≡C bondings.

DNA is unique in being able to store information and the only thing unique in its structure is the sequence of its base which can be arranged in different patterns. Since the RNA sequence pattern is very similar, this suggests a role for it in the retrieving or transfer of messages.

As mentioned above, the structure of RNA is very much like a single strand of DNA. This enables the RNA to compliment the DNA strand just as new nucleotides complement DNA strands during semi-conservative replication.

D. Transcription

This process where the DNA is complemented by bases of RNA leads to a retrieval of stored information, i.e., transcription. It involves RNA bases hydrogen bonding to DNA bases (base pairing) resulting in a hybrid with the RNA strand differing from the DNA by the insertion of uracil for thymine. In this case the DNA strand is called the template and the RNA the complement.

Types of RNA:

1) mRNA carries the message from the DNA into the cytoplasm for protein synthesis.

2) rRNA or ribosomal RNA is found in ribosomes and appear to be structural in role. The ribosomes are blocks made of both protein and RNA on which protein is synthesized.

3) tRNA or transfer RNA are found also in the cytoplasm and their role is to transport activated amino acids to the site of protein synthesis on the ribosomes. There is a specific transfer RNA for each type of amino acid.

The rRNA and tRNA constitute about 96 per cent of the total RNA in the cell, but hybridizing them to DNA strands show that they are copied from a small portion of the total DNA.

We mentioned earlier that the nucleus contained DNA, some RNA and proteins. The proteins in the nucleus are bases, a type called histones (except that sperm have protamines). Experiments suggest that these histones act to neutralize the acids (DNA) so that they cannot always be transcribed except for when transcription is required by the cell.

E. Translation

The message when transcribed into the messenger RNA, are in codes. To decipher this code, the tRNA has an anticodon as part of its structure that will pair with the code on the mRNA. Suppose a message like AAA or GCU are on the mRNA, then the specific anticodon on the tRNA must be UUU or CGA. The other end of the tRNA is coded for a specific amino acid, thus UUU on the anticodon is recognized as bearing the amino acid phenylalanine at the other end of the tRNA and therefore, phenylalanine corresponds to AAA portion on the mRNA and TTT on the DNA strand. For the structural relationships of this process, see Units 3 and 6. [For a more detailed account of translation or transcription see any standard text on Molecular Biology]

For practice do Exercise 32.

Demonstration:

C. P. Misra of Saint Augustine's College suggested the following procedure for demonstrating the presence of nucleic acids.

1. Mark 4 test tubes 1 cm. and 3 cm. from the bottom with a wax pencil.
2. Add yeast solution up to the 1 cm. mark of the second test tube, commercially available RNA to the third and commercially available DNA to the fourth test tube. Leave the first test tube blank as a control.
3. Add Diche Solution [Diphenylamine] to all the test tubes until the 3 cm. mark is reached.
4. Heat the test tubes and their contents close to boiling point for 20 minutes. Cover the mouth of the test tube with cotton plugs.
5. Allow the test tubes to cool for 10 minutes while at the same time noting the colour changes. A blue colour indicates the presence of DNA while a green color indicates the presence of RNA.

   This demonstration can also be assigned to some students as a laboratory exercise.

SELF-TEST

Multiple choice: Select the one best response.

1. Studies of heredity have revealed that the genetic material DNA

   a. is unchangeable.
   b. undergoes massive change in each generation.
   c. is largely kept constant by the precise pattern of its replication and distribution to progency cells.
   d. does show same mutation of nucleotides.
   e. both c and d above.

2. DNA serves as a template for the synthesis of

   a. DNA
   b. messenger RNA
   c. ribosomes
   d. both a and b
   e. both b and c

3. Test tube experimentation indicates that certain chemicals are required for the synthesis of DNA. These include:

   a. messenger RNA
   b. DNA polymerase
   c. DNA primer
   d. both a and b
   e. both b and c

4. RNA differs from DNA by its possession of

   a. adenine
   b. cytosine
   c. guanine
   d. thymine
   e. uracil

5. Which of the following statements fits the CURRENT concept of DNA?

   a. Precise duplication of the molecule is possible because of specific base pairing.
   b. The particles of DNA control cellular activity by their migration through body tissues to a point of action.
   c. The strands of DNA exist in the form of a double helix.
   d. Both a and b above.
   e. Both a and c above.

6. Interpretation of an mRNA code groups to an amino acid sequence is called

   a. transcription
   b. replication
   c. translation

7. The acceptor site (the anitcodon) on tRNA

   a. reacts with an amino acid.
   b. reacts with a ribosomes.
   c. reacts with the code of mRNA.

8. Each tRNA is specific
   - a. for a ribosome.
   - b. because of its sulfur content.
   - c. for an amino acid.

9. The base sequence of mRNA is determined by
   - a. ribosomal RNA.
   - b. nuclear DNA.
   - c. tRNA.

10. RNA is found in
    - a. the cytoplasm only.
    - b. the nucleus only.
    - c. both (a) and (b).

11. Chromosomes are composed of
    - a. DNA alone.
    - b. proteins alone.
    - c. RNA alone.
    - d. proteins and RNA.
    - e. DNA and RNA.
    - f. proteins and DNA.

True-False:

1. Genes belonging to different segments of DNA, function independently.

2. The genes of man and other mammals are presumed to function in a similar manner with those of bread mold and E. coli.

3. Errors in the replication of DNA and the chromosomes do not occur.

4. tRNA is a molecular device for carrying the message of the genetic material from the nucleus to the site of protein synthesis in the cytoplasm.

5. Adenine can bind to guanine.

6. DNA contains uracil.

7. rRNA is the same thing as messenger RNA.

8. DNA can incorporate radioactive thymidine.

9. Genes are used only once in a lifetime.

10. Not all genes are used at the same time.

Discussion Questions

1. Differentiate between semiconservative, conservative and dispersive modes of replication.

2. Explain how each of the modes of replication applies to chromosome and DNA replications.

3. Discuss the differences between RNA and DNA.

4. Discuss the effects a mutation will have on the protein structure.that is coded from that part of the DNA.

5. Review the meiosis.

6. What is a gene? What is the nature of the genetic material at the microscopic level? At the molecular level?

7. Diagram on paper, or build a model of, the structural representation of DNA. How is this organization of molecular structure translated into the proteins of the cell? Why don't all cells of a cellular organism produce all the proteins that are coded in the genetic material? Why do certain specific cells produce only certain specific proteins? As, for example, the keratin protein of hair and epidermal celly by human skin cells and the hemoglobin protein by cells in human bone marrow?

8. What influences the activity of individual genes? Of the genotype as a whole? How does a mutation differ from the nonmutation? What structural changes in the genetic material are associated with mutation?

9. Does it appear reasonable to you that DNA is a molecule able to encode instructions for the structure and activity of organisms as diverse as viruses, bacteria, algae, flowering plants, lobsters, salmon, whales, and man? How does our knowledge of DNA structure and its activity explain the similarities shared by earth organisms? The dissimilarities that distinquish different kinds of creatures?

Seminars

I. One Gene - one protein theory

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Blood That Kills in the Sciences [Published by the N. Y. Academy of Sciences. Vol. 8 & 12. December, 1968.

A. Bearn and J. German III, 1961. Chromosomes and Disease, Scientific American, November, 1961.

E. Zaino, 1964. Paleontologic Thalassemia, Annals of the N. Y. Academy of Sciences; Problems of Cooleys Anemia, 119.

Galton, D. and K. Goldsmith, 1961. Hametology and Blood Groups. University of Chicago Press, pp. 39-45. [This is a book that the teacher will find very useful for discussions on blood].

Soon after the rediscovery of Mendel, interest grew in finding the nature of the gene determinant or factor. This interest led to the simple relationship between idea of the gene and function. This relationship was found in some human diseases.

a) The disease called alkaptonuria is inherited as if due to a single Mendelian recessive gene. Analysis shows that this disease is due to the accumulation of homogentisic acid because the enzyme responsible for breaking this compound is missing in the mutants. Thus, the mutant (or patient) is deficient in the given function.

There are several examples of these type of mutation-function relations known in the biosynthetic pathways. There are exceptions also to the one gene one protein hypothesis where there is more than one growth requirement necessary.

b) Sickle cell anemia - in Blacks.
Thalassemia - in whites.

c) Inherited Diseases

II. Genetics and the future generations.
(this includes effects of nuclear radiation, etc.)

III. Drugs and genetics
(L.S.D. and breakage of chromsomes, etc.)

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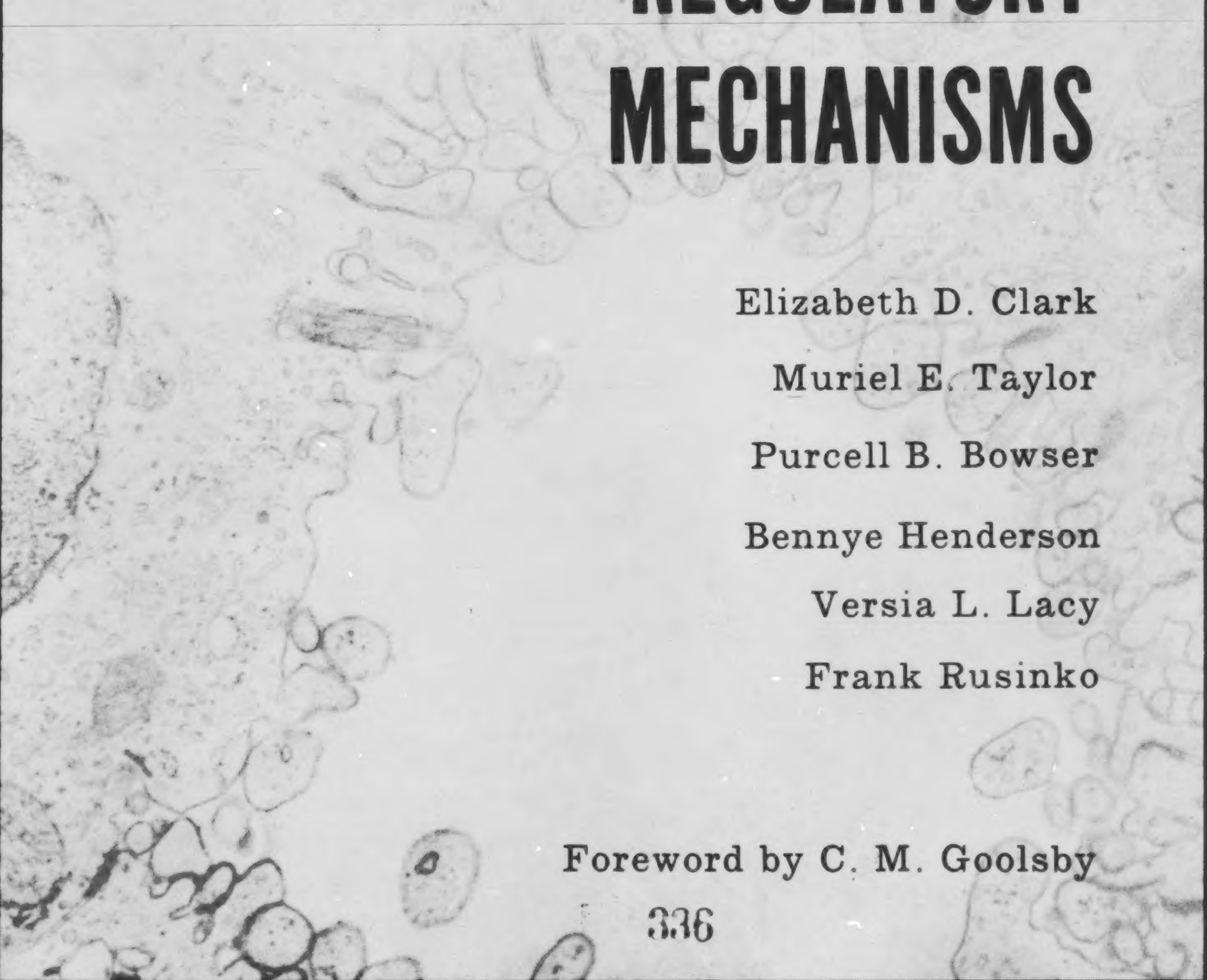

UNIT 6

METABOLISM AND REGULATORY MECHANISMS

Elizabeth D. Clark
Muriel E. Taylor
Purcell B. Bowser
Bennye Henderson
Versia L. Lacy
Frank Rusinko

Foreword by C. M. Goolsby

METABOLISM AND REGULATORY MECHANISMS

FOREWORD

Physiology is a broad subject and one that is interesting to the advanced, as well as the beginning student. This is true in part because it deals with the active processes of being alive and in part because physiology is the study of what is normal. Normal refers to what is usual and implies that there are also abnormalities that are usual. In relation to Physiology, then, there is the study of Pathology which deals with abnormalities in form and function. Since normal function is usual it may not be noticed until some one or some organism comes under study that is abnormal in some way. This was true of Dr. Beaumont's ability to study digestion through the gostric fistula in Alexis St. Martin. Other examples abound where the first realization of abnormality was from a spontaneous deviation from the normal. Physiologists from the time of Claude Bernard on have also performed controlled experiments to determine what functions are normal. Knowledge of physiology therefore, implies a realization of sickness when it occurs and an end-point for treatment when one recovers from an illness.

One of the problems faced by the committee of teachers developing this unit was the selection and sequencing of a few topics in Physiology which would be interesting, intellectually stimulating to the beginning student, and illustrative of some broad concepts in this area.

Charles M. Goolsby, Ph.D.

METABOLISM AND REGULATORY MECHANISMS

Introduction

This unit will be limited to a consideration of those aspects of metabolism involved in providing food and oxygen to the cells and the removal of metabolites and wastes. The regulatory mechanisms will deal with the endocrine and nervous systems as the mediators of integration and coordination.

In this way something important can be said about the digestive, circulatory, lymphatic, respiratory, excretory, nervous and endocrine systems. This means that only passing reference can be made to the muscular, skeletal, reproductive, sensory and integumentary systems. This does not mean that these are unimportant systems in animals but merely that choices were made for introductory purposes.

It is desired in this unit to transmit the general concept that there is a close similarity between the processes and functions in animals, plants and protists. (The basis for this unity is detailed in the unit on The Cell.) Therefore, such aspects of plant physiology as photosynthesis, the transport of water and other substances, and similar topics will be introduced in the corresponding parts of the outline rather than in a separate section.

The general objective sought in teaching this unit include these:

1. Developing an understanding of the source and utilization of energy.
2. Understanding how the body processes are integrated.
3. Understanding the use and disposition of cell products.

Specific Objectives:

1. Helping the student to understand the importance of nutrition and the manner in which nutritional processes are carried out in different species.
2. Aiding the students to understand that ultimately it is cellular respiration which releases energy and makes it available for various uses in the body.
3. Helping the student understand the role of excretion and osmotic control as regulatory mechanisms in all organisms.
4. Providing the student with a basis for realizing why different animals have different types of excretory organs.
5. Developing an understanding of the mechanism by which urine is formed in his own body.
6. Giving the student an opportunity to explore the phenomena of integration and coordination of the major internal functions of the body and how they are controlled by chemicals called hormones.

7. Enabling the student to get a general understanding of hormone reactions so that he will be able to analyze studies of chemical integration in plants, invertebrates and other vertebrates, even though emphasis is being placed on man.

8. Helping the student to understand the role of the nervous system in coordinating body processes.

9. Helping the student to become aware of the structure and functioning of the various parts of the nervous system and their relationship to each other.

PROGRESS INVENTORY

Part A. Encircle letter of correct alternative:

1. The autonomic nervous system
   a. is under voluntary control.
   b. transmits impulses largely to the brain.
   c. utilizes spinal nerves only.
   d. innervates visceral organs.

2. The brain region which controls association, memory and reasoning is the
   a. cerebellum.
   b. medulla.
   c. cerebrum.
   d. thalamus.
   e. hypothalamus.

3. Hormones are produced in
   a. vertebrates only.
   b. animals but not plants.
   c. animals and plants.
   d. plants only.
   e. human beings only.

4. Nervous systems exist in
   a. vertebrates only.
   b. animals but not plants.
   c. animals and plants.
   d. plants only.
   e. human beings only.

5. The development of goiter may be associated with the deficiency or excess of the hormone
   a. insulin.
   b. thyroxin.
   c. adrenalin.
   d. progesterone.
   e. prolactin.

6. Nitrogenous wastes are usually excreted in the form of ammonia by
   a. no living organisms.
   b. many aquatic animals.
   c. mammals only.
   d. all vertebrates.
   e. all animals.

7. Which of the following enzymes acts on carbohydrates?
   a. Pepsin.
   b. Amylase.
   c. Lipase.
   d. Trypsin.
   e. None of the above.

8. Protists do not need an organized circulatory system since the movement of materials within them occurs largely by
   a. capillary action.
   b. cohesion.
   c. transpiration.
   d. excretion.
   e. cyclosis.

9. Which of the following features are common to the respiratory systems of fish, grasshoppers, and man?
   a. Air sacs.
   b. Air tubes.
   c. Air-transporting blood vessels.
   d. Spiracles.
   e. A thin, moist surface for diffusion.

10. The primary activity of plant auxins is to
   a. cause growth of oat seedlings.
   b. bring about curvature of growing stems.
   c. diffuse into the soil and kill competing plants.
   d. regulate plant growth.

Part B. True-False

1. Nutritionally, whales would be classified as autotrophs.
2. Bile is secreted by the small intestine.
3. The blood of mammals serves as transporter of nutrients, gases, hormones, and excretory products.
4. The primary function of hemoglobin is to give blood a red color.
5. Blood plasma is composed chiefly of water.
6. Food produced in the leaves are normally transported in higher plants by phloem.
7. Respiration in green plants takes place in the presence of light only.
8. In a green plant, chloroplasts capture light energy and convert it into chemical energy.
9. Blood is oxygenated in the capillaries of the lung alveoli.
10. An increase in carbon dioxide in the blood stimulates breathing reflexes.
11. Respiratory enzymes are located chiefly in the cell structures called centrosomes.
12. The major end-product of the citric acid cycle is lactic acid.
13. The ultimate source of energy in cellular respiration is hydrogen.
14. Overeating of glucose results in getting fat.
15. Dietary fats, carbohydrates and proteins are interchanged in a metabolic pool.

Progress Inventory Answers

Part A		Part B		
1. d	6. b	1. False	6. True	11. False
2. c	7. b	2. False	7. False	12. False
3. c	8. e	3. True	8. True	13. True
4. b	9. e	4. False	9. True	14. True
5. b	10. d	5. True	10. True	15. True

METABOLISM AND REGULATORY MECHANISMS

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TOPIC OUTLINE

I. Nutrition

- A. Heterotrophic Nutrition

- B. Autotrophic Nutrition
  1. Chemosynthesis
  2. Photosynthesis

II. Systems Supporting Cellular Environments

- A. Digestive Systems
  1. Extracellular and "Intracellular" Digestion
  2. The Human Digestive System

- B. Circulatory Systems
  1. Evolution of Circulatory Systems
  2. The Mammalian Heart
  3. Circulatory Vessels
  4. Microcirculation at Capillaries
  5. Lymphatic Vessels
  6. Circulation in Plants

- C. Respiratory Systems and Gas Transport
  1. Development of Respiratory Systems
  2. The Mechanics of Breathing in Mammals (Man)
  3. The Chloride and Isohydric Shifts
  4. Oxygen Debt
  5. Respiratory Quotient
  6. Basal Metabolic Rate

- D. Excretory Systems and Osmotic Balance
  1. Water Balance and Excretion in Various Environments
  2. Types of Excretory Organs
  3. Structure of the Mammalian Kidney

- E. Endocrine System and Endocrine Control
  1. Some Definitions
  2. Some Groups of Hormones
  3. Glands of the Endocrine System in Human Beings
  4. Feedback Operation of Some Glands in the System
  5. Mechanisms of Hormonal Reactions
  6. Interrelation Between the Endocrine and Nervous Systems
  7. Phytohormones (Plant Hormones)
     - a. Auxins
     - b. Gibberellins
     - c. Kinetin (a Kinin)
     - d. Amo-1618, A Growth Inhibitor

- F. The Nervous System and Its Function
  1. Introductory Remarks
  2. The Neuron and Its Parts
  3. The Central Nervous System
  4. The Autonomic Nervous System
  5. The Transmission of the Nerve Impulse

METABOLISM AND REGULATORY MECHANISMS

ANNOTATED OUTLINE

I. Nutrition

Specific References:
Schmidt-Neilsen (1964) pp. 1-19
Galston (1964) pp. 10-18, 35-62

Alternate References
Simpson and Beck (1969) pp. 66-69
Weisz (1965) pp. 208-217
Goldsby (1967) pp. 64-70
Morrison (1966) pp. 15-40

Nutrition

Nutrition refers to the substances that provide energy needed by cells to continue living, that is, their food. Generally speaking, the food "eaten" by an organism constitutes its diet. The fact is that the different animals and plants are just slightly different in their composition and these subtle differences are what makes them species. The processes by which living or once-living organisms become food for others is discussed under predation in Unit 8. The object is to procure a source of building blocks which can be dis-assembled and re-assembled again into the specific substances of the eater.

A. Heterotrophic Nutrition

In Units 1, 2 and 3 it has been developed that the universe was generated out of protons and electrons (essentially hydrogen) and that there is a continuity between the non-living compounds generated in the forming earth and in its atmosphere. Life began in the ancient seas, which we have described as vast reservoirs of sterile broth (in the "beginning") full of amino acids, the components of the nucleic acids, and numerous small molecules containing energized hydrogen atoms. When the proteins were formed, they were maintained not only by building up a permanent memory for their reconstruction in DNA molecules, but they had to maintain that system with some energy. The energy was extracted from the hydrogens of the small molecules in the ancient sea. So, metabolism of hydrogen-containing compounds was one of the earliest features of the pre-cell and this has been continued (fossilized, if you like) in present-day cells.

In Unit 3--The Cell--the metabolic pathways whereby the energy of hydrogens is extracted for cell use has been presented in some detail. Also, the idea that fats and proteins are also "burned" in the "flame" of the carbohydrates was developed. In fact, the energy is shifted around among the carbohydrates, fats and proteins so that we speak of these as being in the metabolic pool.

The root, trophic, means to feed, as distinguished from tropic, which means to draw toward. Hetero- is a prefix which indicates "different", that is, not the same. We shall consider two big classes of nutritional method called heterotrophic and autotrophic. Autotrophic means literally "self-feeding" and heterotrophic means "different-feeding", that is, getting food from the environment. Actually the metabolism of all living cells begins with the anaerobic breakdown of glucose, although many cells can use many intermediate metabolites in the pathway as "food", that is, as the "beginning" compound(s).

In addition to the carbohydrates, fats and proteins, which represent stored compounds containing energized hydrogen, cells also need certain other small organic molecules which work with nucleotides as coenzymes for the incorporation or extraction of the energized hydrogen. In man these are essential, that is, man cannot make these necessary compounds, so they are called "vitamins". This originally meant amines needed for life, but later they were found not to be amines so the name was changed from vitamines to vitamins.

Another consequence of life having arisen in the ancient seas is the fact that certain salts are needed in the environment. These come mainly from among the 22 lightest elements of the atomic table, but notable are the chlorides, bicarbonates, phosphates and sulfates of sodium, potassium, magnesium and calcium, with those of many other metals being important because they are needed in such small or trace amounts.

The role of water cannot be minimized. It constitutes 70 to 90% of most cells and a loss of liquid water, either by dehydration and evaporation, or by freezing, can destroy the living state.

Therefore, inside of cells, foods become stored as carbohydrates, fats, proteins, and vitamins. Salts and water are also necessary nutrients. These foods must be obtained either in the food supply or by internal synthesis.

B. Autotrophic Nutrition

Part of the genius inherent in the metabolic system is the fact that a wide variety of other systems can "plug in" to it.

The pre-cell was probably well underway 3 to 3.5 billion years ago, At that time there were plenty of nutrients in the seas. The cloud cover was probably still very thick, so that the earth was dark, and virtually all of the oxygen was tied up in carbon compounds or in oxides of the earthy crust. Dr. Barghorn, plant paleontologist at Harvard University, has found fossilized casts of blue-green algae which by sodium-potassium isotope dating he has placed at being about 2 billion years old. Since these are photosynthetic organisms, we could probably place the beginnings of photosynthesis at about 2.5 billion years ago. Prior to that time, however, apparently some cells found themselves separated from their usual source of carbohydrates for energized hydrogens and in need of food. These became adapted to the chemotrophic form of autotrophic nutrition.

1. Chemosynthesis

Some free-living cells, mainly bacteria, can draw on certain inorganic chemical reactions to produce hydrogens. These are attached to compounds which become unstable, thus leaking chemical energy from the molecule to the hydrogen which then, with the aid of ATP is used to reduce carbon dioxide to carbohydrate.

The carbohydrate is then used in the same way as other cells use it. Examples of these reactions are:

$$2H_2O + 2S \longrightarrow 2H_2S + O_2,$$

$$H_2S \xrightarrow[\text{Desulfurase}]{\text{NADP}} NADPH_2 + S$$

$$H_2O + Fe \longrightarrow Fe(OH)_2 + H_2$$

$$Fe(OH)_2 \xrightarrow{\text{NADP}} NADPH_2 + FeO_2$$

$$2NH_3 + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2 + 2H^+ + 2H_2O + \text{energy},$$

$$2H^+ + NADP \longrightarrow NADPH_2$$

$NADPH_2 + ATP + CO_2$ + Ribulose 1,5 diphosphate yields 3 phosphoglyceraldehyde.

This is known as the "dark" reaction.

2. Photosynthesis

With the breaking up of the heaving cloud cover, light could reach the surface of the earth (say, about 2.5 billion years ago). When this happened, chlorophyll, a substance very closely related to the cytochrome enzymes and to hemoglobin, was utilized as a source of electrons for easy energizing with light. Chlorophyll has been detected in space by spectrophotometry--its source being attributed to the head of rockets sent into space in recent years. This would indicate that if chlorophyll can be formed that easily, it was certainly present, and the appearance of light was the only ingredient needed to get a new source of energized hydrogen atoms. The details of the "light" reaction are given in Unit 3. The energized hydrogens were trapped on NADP as NADPH, ATP was produced . Unlike chemosynthesis, the process released gaseous oxygen, and since then has been responsible for raising atmospheric oxygen from about 0% to about 21% of the atmosphere. These materials then participated in the "dark" reaction, previously-invented by the chemosynthetic organisms. (See Unit 3 for reactions.)

$NADPH + ATP + CO_2$ + Rubulose 1,5 phosphate yields 3 phosphoglyceraldehyde.

Both chemosynthesis and photosynthesis, then, provide a way of getting energized hydrogens into the metabolic pathway. The metabolic pathways provide for extracting and storing that energy in ATP and similar triphosphates for use in cell processes, oxidizing the hydrogens to neutral water to keep the system from coming to chemical equilibrium.

Approach

Bring a sandwich (hamburger) to class and display it attractively so that its appearance is appetizing. Using this object, have the students tell what foods are to be found in the sandwich. They should know that there is carbohydrate in the bread, also some protein; protein in the meat, some fat for flavor, vitamins in the meat, bread, lettuce and tomato if present, salt (and pepper for flavor), and water. List these wanted terms on the chalkboard as they are presented so that students will know that they should take notes.

Then proceed with some questions about what happens when such a sandwich is eaten. They will know that it is digested (they may not know into what). Determine their opinions about what happens to the sandwich once it is eaten. What is wasted? what is absorbed? what happens to the materials absorbed? etc. Ask how they would get along if they had a choice of all the hamburgers they could eat while staying in an almost dark lounge day and night, as contrasted with laying out on the beach day and night with nothing but sunlight, fresh air and water to live on for days. This is the lead into the discussion of heterotrophic nutrition, chemosynthetic and photosynthetic nutrition.

For laboratory work, have students do Exercise 32--Photosynthesis and the Synthesis of Starch (See Teacher's Guide to Exercise 32).

II. Systems Supporting Cellular Environments

Specific References:
Simpson and Beck (1969) pp. 198-250
Weisz (1965) pp. 203-208, 218-233

A tissue is an association of cells, usually of similar origin, morphologically integrated and physiologically coordinated to perform some special function.

An organ is an association of tissues, morphologically integrated and physiologically coordinated to support the economy of the body.

An organ system is an association of tissues, morphologically integrated and physiologically coordinated to carry out major functions of the body.

An organism is an association of organ systems, morphologically integrated and physiologically coordinated into an individual.

A superorganism is an association of organisms, morphologically integrated and physiologically coordinated to perform functions which the individual cannot do alone.

-- The late Dr. Alben B. Dawson, Professor of Biology, Harvard University.

In this section we will study some selected organ systems and the ways in which they are morphologically integrated and physiologically coordinated to support the environment of cells so that the living state may be maintained. Life began within a limited range of conditions. When those limits are approached, sickness results. If they are exceeded, the organism dies. The maintenance of fairly constant conditions is called homeostasis.

A. The Digestive Systems

1. Extracellular and "Intracellular" Digestion

Digestion is a term for the breaking up of molecules, especially by hydrolysis, that is, breaking with the insertion of water. The general reaction is:

$$AB \xrightarrow[HOH]{} A\text{-}H + HO\text{-}B$$

This can be done in the laboratory by boiling most foods with acids or alkali. However, as you all know, those kind of conditions cannot be reached in living bodies. Enzymes serve the very practical function of lowering the heat, or other kinds of energy, that could be used for these chemical reactions, so that they proceed fairly rapidly at the relatively low temperatures of the body.

Then:

$$\text{AB} \xrightarrow[\text{HOH}]{\text{AB-ase (enzyme)}} \text{A-H} + \text{HO-B} + \text{AB-ase (enzyme)}$$

For nutrition

Complex carbohydrate (glycogen, starch) $\xrightarrow[\text{HOH}]{\text{Carbohydrase}}$ (Glucose)
n(glucose)

Long chain fatty acids (olein, stearin) $\xrightarrow[\text{HOH}]{\text{B-oxidation}}$ n(acetate)

$$\text{n(acetate)} + \text{n CoA} \longrightarrow \text{n Acetyl CoA}$$

Proteins $\xrightarrow[\text{HOH}]{\text{Proteinases}}$ amino acids
n(amino acids)

The cell membrane generally cannot transport large molecules, so the products of digestion can be transported much more easily, keeping out the undesirable larger molecules which may be "foreign" to that individual. Once inside the cell, they are assembled according to the patterns held in the memory of the DNA molecule, or they are transported out the other side for absorption by the circulating body fluid.

The eubacteria are the simplest-looking cells and are probably the most primitive ones available for study today. These cells secrete their digestive enzymes into their watery environment, where the enzymes do their work of splitting foods. The products of digestion are then absorbed (by active transport) for use in the cell for the derivation of energy for maintenance and synthesis. This is characterized as extracellular digestion. Fungi also carry out this kind of external digestion.

A second pattern of digestion commonly called "intracellular" digestion, is not really different from extracellular digestion. In fact, it is extracellular as far as the cytoplasm of the cell is concerned, that is, "intracellular" digestion is carried on outside of the cytoplasm just like extracellular digestion.

The process is that a bit of food is engulfed (phagocytized) by the organism, forming a vacuole containing the food and some of the outside environment enclosed in a pinched-off sphere of cell membrane. The digestive enzymes are then secreted into its restricted "outside", so that much less enzyme is required to obtain an effective concentration. Numerous mitochondria surround such food vacuoles that are actively digesting because ATP is needed for the active transport of the products of digestion into the cell.

In metazoan animals above the Coelenterates, the food vacuole is replaced by a gut, that is a restricted outside which runs through the animal. This is called the gut, intestine, or alimentary (= nutrition) canal or tract. The inside of the tract is actually outside of the tissues of the animal, but provides a restricted outside into which digestive enzymes are secreted and from which the products of digestion are readily absorbed (by active transport) for transfer to the circulating body fluid and eventual distribution to the cells of the body.

Therefore, we can see that the term "intracellular digestion" is left over from the time before the plasma membrane could be resolved in the electron microscope. There is no validity to the term at present, but it is still widely used.

2. The Human Digestive System

THE MAJOR GLANDS AND FUNCTIONS OF THE PARTS OF THE HUMAN DIGESTIVE TRACT

Part	Major Functions	Major Glands and Their Secretions
Mouth or zone of ingress	Grind food to small bits to increase surface area for chemical exposure.	The parotid, submaxillary and sublingual are major salivary glands. There are numerous smaller buccal glands. All secrete mucous for lubrication and the enzyme ptylin for starch digestion.
Pharynx	To keep food and drink out of the air tubes (trachea and nasal cavity).	No major glands except for mucus secretion.
Esophagus	Voluntary and involuntary (bottom part) movement of food bolus to the stomach.	Esophageal glands secrete mucus. Dry materials which rub mucus off of surface irritate the cells and cause the reflex movements of hiccupping.
Stomach	The pylorus churns and digests foods. The fundus (basket) stores food from larger meal (permits salivary digestion to go on) until pylorus can act on it.	Gastric glands have several types of gland cells. Neck cells secrete anti-anemia factor (intrinsic factor). Chief cells secrete pepsin for protein digestion. Parietal (wall) cells secrete HCl to make pH about 2. Surface cells secrete mucus.
Small Intestine:		
Duodenum (2 + 10 inches)	Carries on alkaline digestion of foods.	Pancreas secretes trypsin and chymotrypsin for protein digestion, lipase for fat digestion, bicarbonate for buffering.

THE MAJOR GLANDS AND FUNCTIONS OF THE PARTS OF THE HUMAN DIGESTIVE TRACT

Part	Major Functions	Major Glands and Their Secretions
Small Intestine (cont.)		
Duodenum (cont.)		The liver secretes bile (stored in gall bladder) as a detergent acting on fats. Crypts of Lieberkuhn and Brunner's glands secrete maltase, sucrase, etc. for sugar digestion. Also the hormone secretin, gastrin, and cholecystokinin are released.
Jejunum	Absorption of digestion products (amino acids, sugars, fats, fatty acids)	Mucus cells (Goblet cells)
Ileum	Continues absorption of digestion products	Mucus cells (Goblet cells)
Large Intestine:		
Cecum and vermiform appendix	No known function in man. In birds and lower animals bacteria making cellulose-digesting enzymes live here.	
Ascending, Transverse, and Descending colon	Reabsorption of water from the chyme. Secretion of salts, especially Calcium.	Mucus cells (Goblet cells)
Rectum	This last 6 inches of the tube is very muscular for the final expulsion of the feces.	Mucus cells
Anus	Involuntary internal sphincter and voluntary external sphincter, together with abdominal muscles, give some control over defecation.	

Approach to a Discussion of the Digestive System

Do Exercise 33--Digestion of Foods (See Teacher's Guide to Exercise 33). Note that Exercises 11 and 13 (if not done in Unit 5) should be done before Exercise 33 is attempted.

For the follow-up discussion the general concept that all living things need a source of stored energy can be introduced with a film loop of animals feeding such as Ealing #81-5027/1 (Paramecium aurelia) Part 1 or #81-5035/1 (Paramecium aurelia) Part 2. Show the film loop without describing its contents beforehand. Perhaps show it twice. Ask if anything the class saw was similar to or different from what students (or other people) do when they eat.

For an added note of interest, provide a few Venus flytrap plants for the demonstration of their ability to digest a bit of ground meat (fly, hamburger, etc.).

The presence of food materials and their identification is covered in Exercise 11. The approach to Exercise 33 makes use of bacterial cultures which indicate that food in the medium is needed for growth of the organisms. The elementary considerations of enzyme action are made in Exercise 13.

B. Circulatory Systems

Specific Reference
Schmidt-Nielsen (1964) pp. 21-31
Ray (1963) pp. 44-58, 70-76
Simpson and Beck (1969) pp. 207-220
Weisz (1965) pp 226-228
Galston (1964) pp. 57-62

In the ancient oceans in which the pre-cell arose, fresh food (substrate molecules) were brought to the community of enzymes by water currents. The same current, at some risk to the integrity of the pre-cellular community, also washed away some accumulating products, such as alcohol, which would eventually be lethal to the system.

After formation of the cell membranes, it was still necessary to keep the internal environment of the proteins as much as possible like that which they had experienced in the open environment. Without ascribing "purpose" to the activity, the cytoplasmic contents moved about, so that one time or another most of the cell contents came close to the membranes. All modern living cells are characterized by the circulation of the cytoplasm within the cells. It is easier to see this in some cells like those of Paramecium and Elodea. Time-lapse photography of other cells also shows this movement.

1. Evolution of Circulatory Systems

Coelenterates represent a two-layered organization for an animal. The inner layer is concerned with food-getting and digestion. There is a space between the inner and outer layer and this is filled with the mesoglea, a kind of body fluid. The mesoglea contains amoebocytes. These phagocytize food at the endoderm and transport it across the mesoglea to feed the ectoderm. This is one of Nature's experiments in assured nutrition, since the cell foods (glucose, amino acids, etc.) could be secreted into the mesoglea and absorbed therefrom by the ectoderm.

In the Flatworms, food is digested in an intricate gut that seeks to distribute the products of digestion into all parts of the animal. Here a flow-through design is used, with water and digestion products being transported through the gut into the mesodermal tissue, and then the excess removed by a peripheral drainage system pumped by flame cells (see Excretion).

Let's skip over the annelida for the moment.

This flow-through design is made more efficient by the "open" circulatory systems of the Arthropods and Molluscs. The food is digested in the gut and the digestion products transferred to the body fluid. The problem is to get the body fluid to bathe all of the cells in something as big as a lobster. To do this a tubular system was invented with a pulsating muscular region (or regions) to move the blood along. It is pumped to the extremities through ventral arteries where it is dumped into the body cavity filled with tissue fluid. This flows back through the organism and is finally picked up by other open vessels, usually in the area where oxygen is added, and then drawn back to the heart dorsally for pumping out to the extremities again.

Beginning with the Annelida (earthworms), which are segmented, a new kind of problem presents itself. The body fluids carrying food and oxygen are somewhat independent for each segment, so some sort of connecting system is needed that will partially equalize the food each can absorb from the gut (being greater toward the anterior). Here the ends of the vessels become connected so that the system is now "closed". Food and oxygen are picked up by the vessels in the dorsal part and drawn forward to the pulsating vessels (hearts). The foods are then distributed by ventral arteries, with diffusion from the vessels equalizing food and oxygen in the individual segments. The flow-through is completed by having its own drainage (nephridal) system.

In the closed circulatory systems of Chordates and Vertebrates, the direction of blood flow is reversed. The heart pumps blood out through dorsal arteries and returns it via ventral veins.

Class	Chambers in Heart
Fish	2 -- 1 auricle (atrium), 1 ventricle
Amphibians	3 -- 2 atria, 1 ventricle
Higher Reptiles	3 1/2 -- 2 atria, a septum partly divides the ventricle
Birds and Mammals	4 -- 2 atria, 2 ventricles

Since the circulatory system of man is rather typical of that in other mammals and in birds, we will examine the details of this system in man.

There are four general aspects of the circulation in man. These are:

1 -- a low pressure circuit to the lungs
2 -- a higher pressure circuit to the body
3 -- the lymphatic system that effects tissue drainage, and
4 -- the excretory system which removes wastes from the blood.

2. The Mammalian Heart

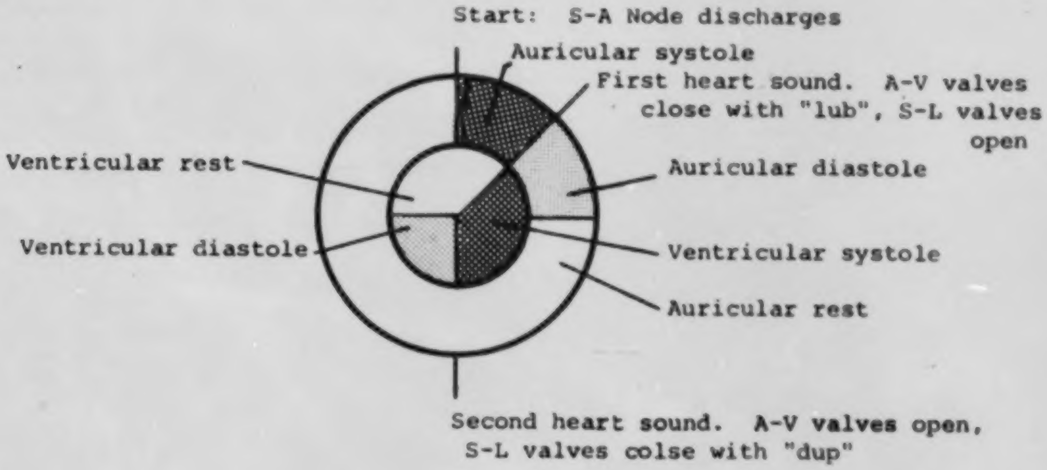
The heart coordinates the operation of two pumps pumping at different pressures because the needs of the body generally and in the lungs are different.

When the heart is contracted, blood is pushed out of the right ventricle at about 75 units of pressure into the pulmonary artery, headed for the lungs. At the same time the tricuspid valve (Remember: tri is right) between the right atrium and the right ventricle is closed, permitting blood to flow into the right atrium from the superior and inferior vena cavae through the foramen ovale.

On the left side, when the ventricle is contracted, blood is forced out through the semilunar valves into the aortic arch. The bicuspid valve between the left atrium and left ventricle is closed, permitting the left atrium to fill with blood from the pulmonary veins.

When the heart relaxes, the semilunar valves in the pulmonary artery and in the aortic junction close, preventing the just-pumped blood from returning to the heart. On the right side, the tricuspid valve opens and the blood that has filled the right atrium flows into the right ventricle. On the left side the blood that filled the left atrium flows into the left ventricle through the now-open bicuspid valve. When the heart contracts again, the bicuspid and tricuspid valves will be forced shut while the semilunar valves to the pulmonary artery and to the aorta will open and blood will be forced into these vessels on contraction of the ventricles.

The sino-atrial node (S-A Node) is located on the edge of the foramen ovale. It automatically generates an electrical impulse that is propagated across the cell membranes of the atria. In the right atrium, near the tricuspid valve is located the Atri-Ventricular Node (A-V Node). This picks up the impulse from the atrial muscles and transmits it rapidly to the apex of the ventricles through some special muscle cells that make up the Bundle of His. The bundle divides into a number of Purkinje fibers extending from the apex up along the walls of the ventricles. An impulse from the S-A Node causes the auricles to contract when the ventricles are relaxed. The impulse then travels through the Bundle of His to cause contraction of the ventricles, starting at the apex, thus forcing the blood out the right direction. These events are arranged so that the heart also gets some rest. In fact, the heart rests about 3/4 of the time. Here is the heart cycle. At 72 beats/minute, each 1/8 of the circle represents .1 second duration.


Start: S-A Node discharges
Auricular systole
First heart sound. A-V valves close with "lub", S-L valves open
Auricular diastole
Ventricular rest
Ventricular diastole
Ventricular systole
Auricular rest
Second heart sound. A-V valves open, S-L valves colse with "dup"

3. Circulatory Vessels.

The pulmonary artery divides and enters the right and left lobes of the lung. Here it subdivides until it becomes capillaries that spread against the thin walls of the lung alveoli. The capillaries run together to form small venules, then larger veins. Two pulmonary veins drain each lung and the four vessels empty into the left atrium. The alveolar surface in a normal man is about equal in size (area) to a singles tennis court. Because of the tremendous capillary bed, the pressure in the pulmonary system remains low -- 30 to 50 units of pressure.

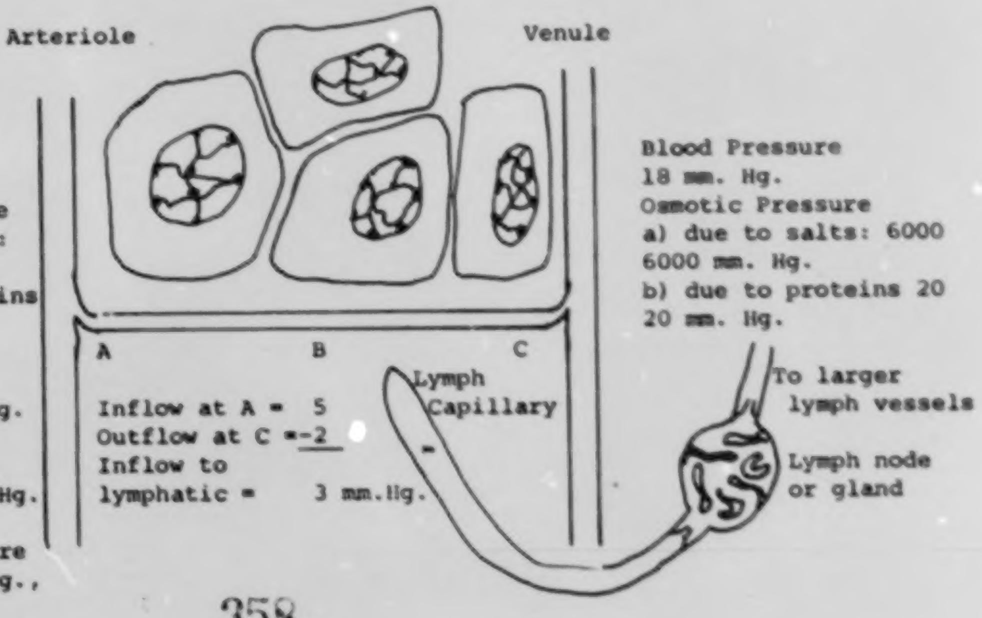
The first vessels leaving the aortic arch have their openings behind the semilunar valves. These are the coronary arteries that nourish the heart muscle. [J. C. once raised the question as to whether or not the coronary arteries contradicted the definition for an artery as a vessel conducting blood away from the heart. Superficially it appears to go toward the heart. Actually, the blood is moving away from the chambers of the heart, but eventually flows back into the heart chambers.]

Near the top of the aortic arch the carotid arteries lead to the head. These are very important because the brain needs food and oxygen. Also coming off of the aortic arch are the brachial arteries to the arms and hands. The mesenteric arteries supply the intestines and visceral organs of the abdominal cavity. The renal artery supplies the kidneys for filtration. The lower end of the dorsal aorta divides to give rise to two iliac arteries supplying the legs and feet. Capillaries in the extremities coalesce to form venules and then large veins, returning the blood to the heart. The jugular veins form in the head and lead back to the chest. From the hands and arms the subclavian veins come together to form the superior vena cava. The jugulars connect into the subclavian veins near the vena cava. In the legs the big veins are the femoral veins. These join to form the inferior vena cava which runs alongside of the descending aorta. Various mesenteric veins join the vena cava.

Capillaries arising on the intestine form a vein that leads, not to the vena cava, but to the liver. This is the hepatic portal system. From the liver the blood rejoins the vena cava through the hepatic vein. Both the superior and inferior vena cavae join at the heart (foramen ovale).

4. Microcirculation at the Capillaries.

The large vessels are conductive (aorta) and distributive (brachial, carotid, mesenterics, etc.). Blood nutrients and oxygen cannot go through the walls of such vessels. The capillaries are the functional part of the system. It is through them that food and oxygen are made available to the cells, and the carbon dioxide and metabolites are removed.



Blood Pressure
25 mm. Hg.
Osmotic Pressure
a) due to salts:
6000 mm. Hg.
b) due to proteins
20 mm. Hg.

Outflow at A =
25 -20 = 5 mm.Hg.

Inflow at C =
18 -20 = -2 mm.Hg.

If blood pressure
at B is 20 mm.Hg.,
then flow = 0.

Inflow at A = 5
Outflow at C = -2
Inflow to
lymphatic = 3 mm.Hg.

Blood Pressure
18 mm. Hg.
Osmotic Pressure
a) due to salts: 6000
6000 mm. Hg.
b) due to proteins 20
20 mm. Hg.

5. Lymphatic Vessels

Capillaries form an important part of the intestines. The surface area for absorption in the intestine is increased by finger-like projections called villi. Capillaries and lymph capillaries reach into these villi to pick up the products of digestion. Sugars and amino acids go to the blood capillaries. About 80% of the fats go to the lymph capillaries. Fat suspended in water looks milky, so that the lymph vessels in this region are known as lacteals.

The lymph vessels lead into filtering devices, the lymph nodules. Here any foreign bacteria are phagocytized. If the bacterial load is large because of an infection, the lymph glands swell with pus cells (lymphocytes). Lymph nodes are mostly found at the joints and in the abdominal cavity.

Lymph vessels from the head and right arm drain into the right subclavian vein. Lymph vessels from the lower part of the body form a large lymph trunk, the thoracic trunk. The rest of the body not drained by the right lymphatic vessel drains into the thoracic trunk which empties into the left subclavian vein near the junction with the jugular vein.

6. Circulation in Plants

The circulatory system in plants operates with only a few, slowly-moving parts. It takes advantage of osmotic pressure and gravity much more than does the animal type circulatory system, and in fact is just as ingenious in its conception as is the circulatory system of man. Only the plants above the Bryophytes have these vascular systems.

There is no equivalent of the heart from which to "start", so let us begin our consideration at the root.

The roots near their tips are covered with root hair cells. These cells have content so that there is an osmotic gradient set up which draws water into these cells. They have thin cell walls, and so would swell and burst were it not that they pump the water out through the inner wall membrane to other cells. Increasing the osmotic content (protein and other solutes) brings the water finally to the xylem tubes. There are two tubular systems between the roots and the leaves. The xylem conducts water upward to the leaves and the phloem brings water and sugar downward to the roots.

The rise of water in the xylem is affected by these factors:

Osmotic attraction in the root hairs (root pressure)
Capillary action in the small bore of the conducting tubes (cohesion)
Evaporation through the stomata in the leaves, and lenticels producing a condition of tension.

The water and salts conducted upward are exuded into the spaces between the leaf cells. The resulting fluid contains water, salts, dissolved gases (carbon dioxide and oxygen), synthesized food (sucrose), and metabolic wastes and other special products. This material is conducted downward by the phloem. The sugar goes to feed all the living cells of the cambium and of the root system.

Approach for the Discussion of the Circulatory Systems

Before class set up the following demonstrations:

a. Daphnia under high dry of the microscope, using the phase contrast microscope, if possible. Affix a Daphnid to a microscope slide with a small dab of petrolatum (e.g., Vaseline). Make a ring with petrolatum around the animal, fill with culture water and apply a coverglass.

b. Capillary circulation in the tail of the fish. Place a guppy or small goldfish in a half petri dish. Cover the front 2/3 of the fish with a wad of wet cotton or gauze. Break a microscope slide by scoring it first with a diamond point or other glass cutter. Place half under the tail for support and half on top of the tail to keep it still. Add a little water to the dish and observe under low, then high power. Select an area of the tail where the blood cells and the flow through the small vessels is clearly seen.

Allow some time for the class to look at these demonstrations and answer questions that are raised. Then, show the film "Heart and Circulation" (Encyclopedia Britannica) or the filmstrip "Our Heart and Circulation" (The Human Body Series. Ward's Natural Science Establishment).

A model of the human torso is good for tracing and identifying the various major blood vessels. In most such models the heart is removable and opens to show the location of the valves. If not, a separate model of the heart can be used for this part. A beef heart can be obtained to demonstrate the location of the valves and vessels. This usually requires direct purchase from the meat packer since it is customary to remove all of the heart vessels and sometimes the atria before marketing hearts.

Prepared slides of monocot stem and dicot leaf may be used to show salient features of the plant circulatory system. Kodachrome slides of these plant tissues may also be used to demonstrate their structure.

C. Respiratory Systems and Gas Transport

Specific References
Weisz (1965) pp. 240-243
Simpson and Beck (1969) pp. 222-230
Schmidt-Nielsen (1964) pp. 13-25, 32-35

1. Development of the Respiratory Systems

As is true with food and water, the gases needed by the one-celled organisms can diffuse in and out of the single cell easily enough so that special apparatuses are not needed. Anaerobic organisms usually yield carbon dioxide, hydrogen, methane, ammonia (gases of the primitive earth atmosphere).

In plants, the gases oxygen and carbon dioxide dissolve in the tissue fluid of the leaf, simple diffusion through the aqueous medium being the mechanism of operation.

In animals below the Mollusca, diffusion through the body wall is the rule, even for such large animals as the marine lugworm (Arenicola) which may be up to an inch in diameter.

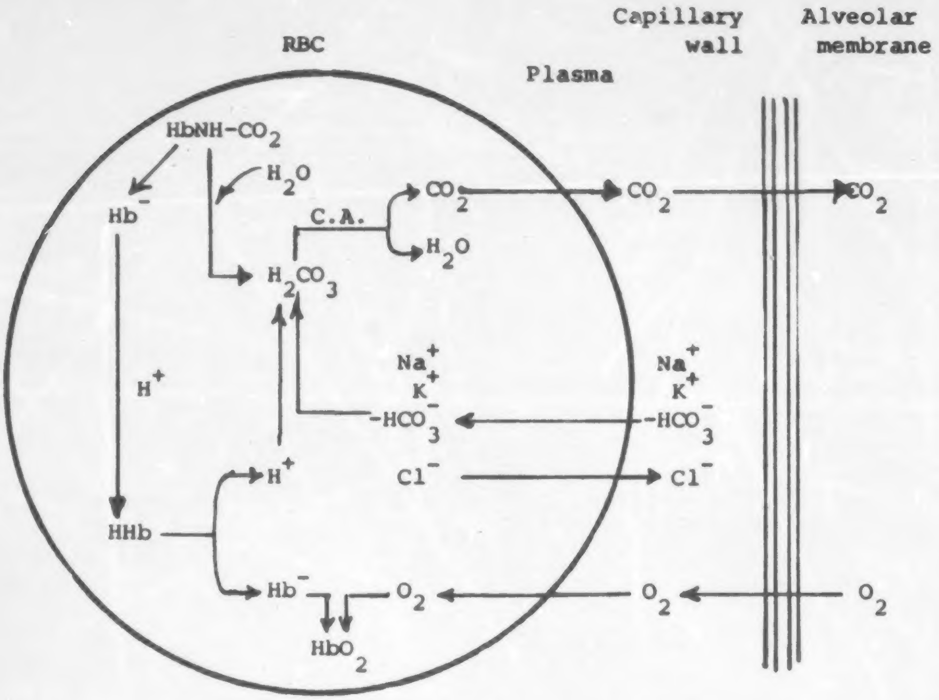
In the Arthropoda a highly developed gill is seen, and this is also true for the molluscs. A gill is an organ for bringing the circulating blood into the closest proximity with the dissolved gases in the water. In most cases water is taken in by mouth and thereby pumped across the gills. This is also true of aquatic vertebrates, such as sharks and fish, and the amphibians when they are tadpoles. In molluscs ciliary beating creates currents to bathe the gills with oxygenated water. Adult amphibians can survive very well submerged in water because the skin surface acts as a supplement to the lungs in bringing the blood near the oxygen in the water. Some Arthropoda (insects and spiders) have tracheids which conduct gas exchange with the tissues.

Lungs are necessary for animals that spend part or all of their time away from the water. Amphibians have lungs, but so also do some fish (the Dipnoi). Birds and mammals all have lungs, and breathe air, even if they spend part of their time submerged in water as do whales, porpoises and hippopotamuses.

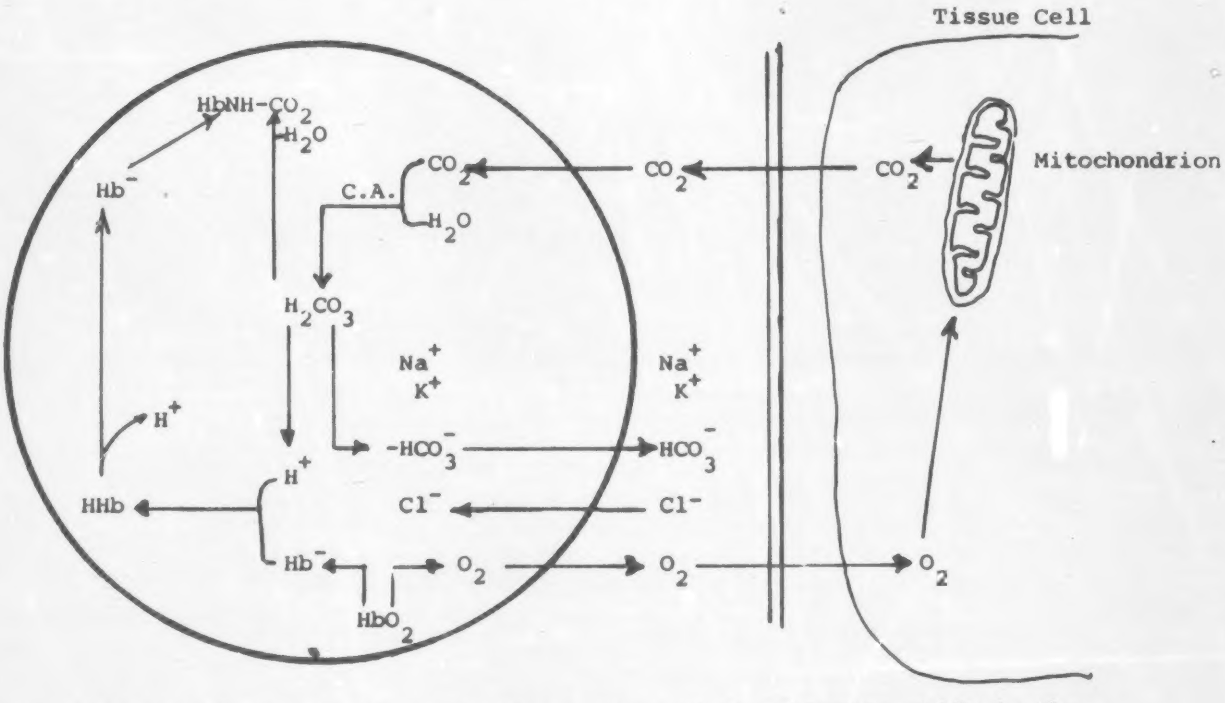
Fish do not have nostrils and a nasal cavity. When these developed in amphibia the nasal cavity communicated with the pharynx, and the lung system and the tubes associated with it developed from the floor of the pharynx. Thus, the food and air passages cross each other at the pharynx and some method has had to be devised to keep food out of the breathing passages.

2. The Mechanics of Breathing in Mammals (Man)

Two methods of breathing are used by mankind. Costal breathing involves raising the rib cage, increasing its size, and therefore creating a partial vacuum which is satisfied by the inflow of air to the lungs. When the ribs are relaxed, part of the air is forced out. This is costal (rib) breathing and is used most by men.


Capillary wall
Alveolar membrane
RBC
Plasma
HbNH-CO2
H2O
Hb⁻
CO2
CO2
CO2
C.A.
H2O
H2CO3
Na⁺
K⁺
Na⁺
K⁺
H⁺
-HCO3⁻
-HCO3⁻
H⁺
Cl⁻
Cl⁻
HHb
Hb⁻
O2
O2
O2
HbO2

At the lungs the bicarbonate shifts into the RBC and the chloride ion shifts out to the plasma to maintain the buffering balance there. The bicarbonate is then reduced to carbonic acid and split to carbon dioxide by carbonic anhydrase (C.A.) Thus, carbon dioxide is transported as bicarbonate and changed back to CO_2 by RBC.


Tissue Cell
HbNH-CO2
H2O
Hb⁻
CO2
CO2
CO2
Mitochondrion
C.A.
H2O
H2CO3
Na⁺
K⁺
Na⁺
K⁺
H⁺
-HCO3⁻
HCO3⁻
H⁺
HHb
Cl⁻
Cl⁻
Hb⁻
O2
O2
O2
HbO2

The isohydric shift at the tissue is the reverse of the chloride shift in the lungs.

A second method of expanding the volume of the chest cavity is to lower the diaphragm. This is a muscular sheet something like an inverted cup. Contraction of the muscles flattens it somewhat, creating a partial vacuum satisified by the inflow of air. On relaxation, air is pushed out of the lungs. This is diaphragmatic breathing which is used mostly by women because of the restrictive clothing usually worn around the chest.

The rate of breathing is regulated by the amount of carbon dioxide in the blood. This is because the carbon dioxide reacts with water to form carbonate acid which affects the breathing center in the medulla, stimulating it. If one takes several deep breaths, breathing out more than the normal amount of carbon dioxide, then we say "over ventilation" has occurred, and breathing will stop for a few seconds to allow the carbon dioxide concentration to return to normal.

Terms associated with breathing are:

eupnea--normal breathing made without effort
hypernea--especially deep breathing
dyspnea--labored, painful breathing
apnea--stopped breathing
Cheyne-Stokes breathing--alternate dyspnea and apnea commonly called the death rattle, typical of the dying person

Special breathing reflexes include:

laughing
coughing
sneezing
singing

The partitioning of the amount of air breathed, as measured with a spirometer, is as follows:

tidal air-- the air normally breathed in and out--about 500 ml.
complemental air--the air in addition to the normal inspiration that can be breathed in
supplemental air--the air in addition to the normal expiration that can be breathed out
residual air--the air that cannot be forced out of the lungs, even by squeezing them because the air passages collapse
vital capacity--the total amount of air that can be breathed in and out (supplemental, tidal, and complemental air combined)

3. The Chloride and Isohydric Shifts (How Gases are Exchanged at the Lungs and In the Tissues)

The lower animals make use of several pigments which have an affinity for oxygen for transporting oxygen from the region of aeration to the tissues. These include erythrocruorin (Annelids), Hemocyanin (Molluscs, some Arthropods), Chlorocruorin (Arthropods), and a vanadium pigment in prochordates. Hemoglobin is the respiratory pigment of the vertebrates and is found in red blood cells (hemoglobin) and in red muscles (myoglobin). It contains the metal iron and some specific proteins which differ from species to species, but all of which belongs to a class of proteins called globins.

Hemoglobin has a very strong affinity for carbon monoxide to form methemoglobin, a good affinity for oxygen (oxyhemoglobin) and a faint affinity for carbon dioxide (carboxyhemoglobin). The reaction at the lungs is called the chloride shift because chloride shifts out of the RBC into the plasma to balance the inshift of bicarbonate to be broken down by the enzyme carbonic anhydrase, into carbon dioxide and water.

About 5% of the carbon dioxide is carried as carboxyhemoglobin, the rest is carried as bicarbonate ion in the plasma.

The oxygen is attached loosely to the hemoglobin (not a covalent bond).

The enzyme, carbonic anhydrase, is very important. Bicarbonate is brought into the RBC to be broken down to carbon dioxide and water which is then released into the plasma and diffuses into the lungs.

At the same time oxygen from the lungs attaches to hemoglobin ion formed by the ionization of reduced hemoglobin (HHb).

At the tissues the process is reversed, with oxygen given off and carbon dioxide being taken up. The concentration of oxygen at the cells is 5% and carbon dioxide is about 4%. In exhaled air the carbon dioxide is about .4% (.04% in air), and the oxygen is about 10% (21% in air).

4. Oxygen Debt

The oxygen from breathing is used by cytochrome a_3 to make water from hydrogen ions (H^+) and electrons coming off of the cytochrome system. If breathing cannot keep up with the demand for oxygen by cytochrome a_3, then the system works at capacity to bring hydrogens through, but the excess hydrogen is stored by reducing pyruvate to lactic acid. When heavy work ceases, 1/5 of these hydrogens are sent through the cytochrome system to water, the other 4/5 go back up the anaerobic railroad to be stored as glycogen. This ability to bank excess hydrogens is called accumulating an oxygen debt. Deep breathing (panting) after heavy work or exercise supplies the extra oxygen needed to satisfy this oxygen debt. A lack of oxygen will cause the system to come to equilibrium and then death by asphyxiation ensues. Conditions relating to the availability of oxygen to tissues are classed as:

anoxia--lack of oxygen
anoxic anoxia--lack of oxygen due to lack of oxygen in breathed air (smothered)
histotoxic anoxia--from cyanide poisoning, where the cytochrome iron became reduced by cyanide so the system comes to equilibrium
anemic anoxia--lack of oxygen at the tissues due to a shortage of red blood cells to carry oxygen
stagnant anoxia--lack of oxygen at tissues because the blood isn't moving, as when a tourniquet stays on too long, or the blood supply has been cut off by a clot (thrombus) then broke loose from a wound (embolus)

Other terms are:

hypoxia -a reduced amount of oxygen present, and
anoximeia --a reduced amount of oxygen in the blood.

5. Respiratory Quotient

The respiratory quotient is the ratio of carbon dioxide given off to the amount of oxygen used (CO_2/O_2). For a pure carbohydrate metabolism the ratio is 1.0. When fat is being burned, there is more hydrogen being consumed, so that the ratio goes to 0.71. For proteins, the amount of carbon to hydrogen is also lower, so that the R.Q. is 0.8. A good mixed diet gives an R.Q. of about 0.83.

6. Basal Metabolic Rate (BMR)

The BMR is the amount of oxygen used per square meter of body surface (a function of weight and height). It is higher for women than for men, and higher in children than adults. It is measured when the person is awake, at complete rest, in a post-digestive state (12 to 18 hours), and at psychological ease.

The energy in food is measured in calories (rather than in joules, foot pounds, etc., even though energy is energy and can be expressed in any terms used for expressing energy).

Carbohydrates	4 calories/gram
Protein	4 calories/gram
Fats	9 calories/gram

The number of calories required for normal people doing these jobs, has been determined experimentally to be:

Sedentary students	2,400 cal.
Carpenter	3,200
Stone mason	4,400
Football player (during season)	4,400
Lumberman	7,000
Secretary about	1,500

Approach to Discussion of Respiratory Systems and Respiration

Do Exercise 34--Measurement of Oxygen Use (See Teacher's Guide to Exercise 34.)

D. Excretory Systems and Osmotic Balance

Specific References
Schmidt-Nielsen (1964) pp. 47-67
Solomon (1962) Scientific American
Smith (1953) Scientific American

Alternate References:
Simpson and Beck (1969) pp. 230-232
Weisz (1965) pp. 316-320
Wilson and Loomis (1962) pp. 146-157
Langley (1965)
Barrington (1968) pp. 125-179

The amount of salt in the ancient seas in which the living state arose was just about right for the enzyme activity of most proteins. Too much salt will precipitate some proteins, too little will also affect them adversely sometimes. It is important to the cell to keep the salt content within certain limits because it will change with the external salt concentration. The excretory system (kidneys, sweat glands, large intestine) and to a lesser extent the lungs are involved.

Salts are needed for the irritability of cells. Some enzymes require a small amount of metallic ion (Ca^{++}, Mg^{++}, etc.) for their activity. Salts also contribute to the osmotic activity inside cell membranes and the depletion of salt can have deleterious results in both plants and animals.

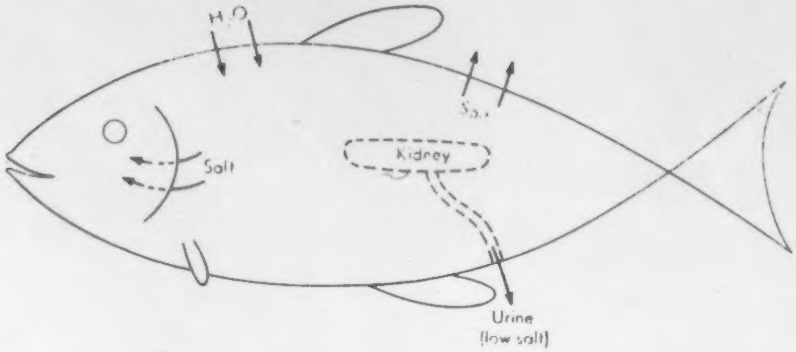
1. Water Balance and Excretion In Various Environments

a. Most marine invertebrates evolved in the sea and have body fluids that are isosmotic (isotonic) with sea water (Note: sea water does not have the same salinity at all locations. It varies widely from almost fresh water in the North and Caspian Seas to about 3.5% in the mid-Atlantic Ocean.).

b. The next environment to be colonized by living things were the mouths of rivers. Some marine forms, crabs and some molluscs, can adapt quite well to the brackish water where fresh-water rivers and the sea meet.

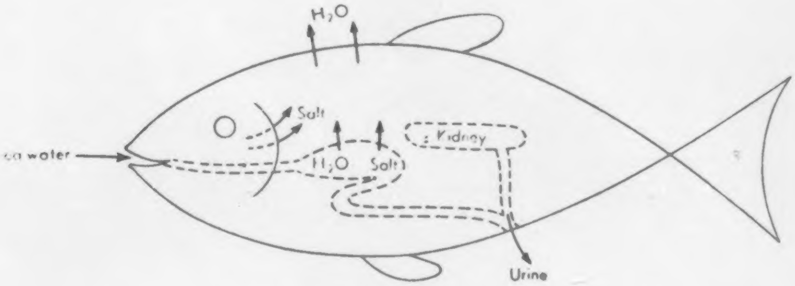
c. The invasion of fresh water necessitated a more efficient kidney. The tissues that were isotonic with sea water could not survive without the salt, and so take in a lot of fresh water which they have to eliminate. They conserve the salts and excrete the water. Let us look at some data for a typical fresh water fish.

We can measure the relative salt concentration in body fluids by measuring the temperature at which they freeze or melt. In these cases we are about to discuss, the freezing point depression (1.86 °C/mole solute) is represented by the Greek letter delta (Δ).



The fresh-water fish has a higher salt concentration than the water, and therefore loses salt while water enters the body. Although this exchange is pictured as taking place from the general body surface, much of it occurs in the gill, which is more permeable than the skin. Water is eliminated as urine, and the salt loss is compensated for by active absorption of salt in the gill.

The bony fishes originated in fresh water, then some of them migrated back to the sea. In this case, their body tissues were more dilute than sea water and they had to adapt to the salty conditions there. Their main problem is that they are being dehydrated by exosmosis. In order to keep from being dried up in the middle of the ocean they drink tremendous amounts of water However, this loads them up with salt, so they excrete most of the sodium and potassium at the gills, and the magnesium and sulfate are excreted at the kidneys. The urine is small (3-4 ml./day) compared with about 300 ml./day for their fresh water cousins.



A fish living in the sea has a steady loss of water because the salt concentration in sea water is higher than in the fish. To compensate for the water loss, the fish drinks sea water. The excess salt taken up is excreted by the gills.

Sharks also evolved in fresh water, but they solve their problem a little differently. They hold a large amount of urea in the blood instead of excreting it. This brings their osmotic pressure inside to about what it is outside, but it also makes shark meat very unpalatable.

2. Types of Excretory Organs

a. Most unicellular organisms seem to be able to pump excess water out of the cell through the cell membranes without collecting it in a vacuole. Other Protozoa and Porifera form contractile vacuoles, for more convenient pumping out of excess water accumulating by osmotic diffusion.

b. In the Flatworms, flame cells (Protonephridia) are found. These are hollow cells with a tuft of cilia that beat to move the fluids diffusing into the hollow space into the channels leading to the outside (at the excretory pores).

c. In insects there is a special adaptation of the intestine, the Malpighian tubules, which collect the nitrogenous wastes, and combine it with carbon dioxide to form uric acid. Uric acid can be excreted directly without the necessity of being washed out by water (as is the case with urea). Therefore it is an advantage to insects and birds which must conserve weight in order to fly.

d. Nephrida are funnel-shaped tubes which collect water and wastes from the body fluids of the annelids. This leads through coiled tubules to a small bladder and from there to the outside through a nephridiopore. Each segment has two of these nephridia.

e. In the crayfish and lobster the kidney is called the green gland and is located in the head. It consists of a coelomosac which leads into a labyrinth where the urine is concentrated, and finally into a bladder which opens through a pore just under the antenna. They are also called antennary glands.

f. In frogs, the mesonephric kidney involves a combination of a glomerulus filtering the blood, and a cilliated funnel-like tubule leading to the coelom. These connect with the Wolffian duct which leads to the base of the bladder and which connects with the cloaca.

g. Birds and mammals have a metanephric kidney as adults. (Mesonephric kidneys occur in some early embryological stages). This functions in two ways: one, to get rid of undesired materials from the blood, and two, to create an osmotic gradient in which this can happen. We shall take the human kidney as being a typical kidney for this group.

3. Structure of the Mammalian Kidney

a. Gross anatomy

The kidney is shaped like a large bean and when cut in sagittal section one sees that there is a large artery, the renal artery and vein. The renal vein connects to the large dorsal vessels. The body of the kidney is divided into a cortex and a medulla by the arciform vessels. The inner part of the tissue forms into one or more pyramids connected by membranous vestibuli to the calyx of the organ, and this latter part is continuous with the ureter connecting to the urinary bladder. The bladder empties through a urethra that extends to the outside.

b. Histology

An afferent arteriole brings blood to the glomerulus (grape), which is enclosed by the capsule of Bowman. The arteriole breaks up into capillaries and then continues as an arteriole (the only place in the body where capillaries join to form an arteriole again). The capsule leads to the proximal convoluted tubules, then passing the arciform line, extends to the peak of the pyramid as Henle's loop and returns. The tube convolutes again, coming in contact with the originating glomerulus, and finally empties into a collecting tubule. The name, collecting tubule, may imply that it only conducts the urine away, but its function is to finally concentrate the urine. The arteriole finally breaks up into capillaries that spread over the convoluted tubules so that they can reabsorb the materials to be kept by the body.

c. Physiology.

The afferent arteriole is normally under about 75 units of pressure and the osmotic pressure due to proteins is about 20 units of pressure. This means that the filtration pressure is about 55 units of pressure in the operating nephrons. There are about 1 million of these in each kidney so that all of them don't have to work at once. During normal activity the kidney will filter a volume of blood equal to the total volume in the body about once every minute. In work or exercise, the time will be shorter. In this way about 600 liters of fluid are filtered out of the 5 liters of blood in the average body every 24 hours. The final urine is 1.5 liters, so about 598.5 liters of fluid are reabsorbed and returned to the blood.

All materials with molecular weights of less than 70,000 are filtered through the glomerulus into Bowman's capsule--sugars, amino acids, vitamins, salts (all goodies), as well as the waste products, urea (made in the liver), and other products (See Exercise 35).

In the proximal convoluted tubules about 85% of the usable items (glucose, amino acids, vitamins, salts, etc.) are reabsorbed. The other 15% will be picked up in the distal convoluted tubules. The remaining filtrate contains considerable amounts of sodium chloride. When sodium ion is pumped, the chloride will follow passively. As the filtrate passes down the loop of Henle, the sodium is actively transported out of the tubule. This increases the osmotic activity of the intercellular fluid in the kidney from about 300 units at the arciform artery to about 1200 units of activity at the tip of the pyramid. The ascending limb of Henle's loop is impermeable to water so it will not dilute this osmotic gradient too much.

As the collecting tube goes through this osmotic gradient on its way to the tip of the pyramid, excess water is withdrawn, the amount depending upon the amount of antidiuretic hormone acting from the posterior pituitary gland. By the time it reaches the tip of the pyramid, the urine is much more hypertonic than the blood (300 units for blood and 1200 units of osmotic activity for urine). Note: The waste products of urine are not secreted into the urine by the tubules, but rather are put there at the glomerulus and just not taken out again.

The kidney tubules will reabsorb about 160 mg. glucose for each 100 ml. of filtrate. Normally the blood level does not exceed this, even after a meal. People with insulin deficiencies (diabetes mellitus) will reabsorb 160 mg.% of glucose, maybe even more. The problem is that the blood sugar in untreated cases will be higher than 300 to 600 mg.%; some cases have been reported to have 2000 mg.% glucose. This leaves some glucose in the urine. Because it raises the osmotic activity, a lot of water is needed to satisfy the osmotic requirement, consequently untreated diabetics will form about 6 to 8 liters of urine a day. This volume has to be replaced by drinking an equal amount of water. Treatment with insulin returns this volume to 1.5 liters of urine a day.

If the posterior lobe of the pituitary is damaged, so that it cannot store antidiuretic hormone, then the collecting tubules do not concentrate the urine and the patient will form from 20 to 30 liters of very dilute urine a day. This volume has to be replaced by drinking. However, treatment with posterior pituitary extract returns the urine output to normal. This disorder is called diabetes insipidus.

When a person sweats a lot and doesn't take salt, he loses a lot of water and salt, so that he may suffer cramps, apathy, stupor, headache, weakness, nausea and vomiting. All of these symptoms can be prevented by taking extra salt.

Prolonged vomiting, and diarrhea cause one to lose a considerable amount of water. Because of HCl loss in vomiting, alkalosis may result. In diarrhea, the loss of bicarbonate may result in acidosis, similar to that in untreated diabetes. In kidney disease there can be a retention of nitrogenous wastes, sulfates and phosphates. Also, there will be an increased permeability to the proteins normally prevented from entering the filtrate. Albumin is commonly found in the urine when kidneys disfunction.

The kidney has a distinct influence on the conservation of body water (but does not control it), excretes certain ions and so influences the general pH of the blood (but does not control it), and therefore is important to the economy of the body. It does not warn that water content is too high or too low; the sense of thirst warns when water is getting low.

Approach to the Discussion of Excretory Systems and Osmotic Balance

Do Exercise 35--Urine Analysis (See Teacher's Guide to Exercise 35).

The exercise can be followed by a study of the film "Excretion" (AIBS) which introduces comparisons of various excretory organs and presents the chief functions of the mammalian kidney. The film should form the basis for a discussion leading into the topics expanded above.

E. Endocrine System and Endocrine Control

Specific References

Schmidt-Nielsen (1964) pp. 103-112
Galston (1964) pp. 73-88

Alternate References

Curtis (1968) pp. 326-332, 342, 593, 610-613
Turner (1967) Chap. 1-3.

Scientific American Offprints, Freeman & Co. San Francisco

#	
8	Fieser. Jan. 1955
14	Gray. May 1950
42	Thompson. May 1955
86	Rasmussen. April 1961
110	Salisbury. April 1957
113	Naylor. May 1952
163	Csapo. April 1958
167	Steward. Oct. 1963
188	Levy. July, 1964
1111	Overbeck. July 1968
1122	Zuckerman. March 1957
1145	Bonner. June 1969

1. Some Definitions

Hormones are chemicals secreted from cells in one part of an organism (animal or plant) which are carried by body fluids to other cells where they exert their effects. The word hormone means "to excite" or to stir up and this is done first by changing the environment of cells, and secondly by processes within cells. Not all cells of the organism respond to hormones, so those that do are often referred to as target organs.

Phytohormones are hormones produced in plants.

Neurohormones are produced in nerve cells and stored there before being picked up by the body fluids for distribution. These are distinguished from the neurohumors, which are the secretions of nerves. There are two groups in vertebrates--the acetylcholine-like neurohumors are destroyed soon after release by neuropodia (axon ends). The adrenalin-like neurohumors are secreted from the cells of the sympathetic nervous system and are characteristically picked up by the body fluids and distributed to target organs. Adrenalin action, therefore, is much more general and long lasting.

Parahormones are chemicals that have a regulatory effect, but which are formed or released by cells in general. Examples are carbon dioxide and glucose.

Pheromones are produced by insects, particularly by bees and ants. They are secreted from the sting and form a scent cone which fades in a few minutes. Other members of the insect social group are guided to food supplies by pheromones. Among the moths and butterflies the secretion is often associated with the attraction of the opposite sex or with alarm signals.

2. Some Groups of Hormones

Steroid hormones are those derived from cholesterol. They are produced in the adrenal cortex and gonads. They include such substances as cortisone, the estrogens, progesterone, and testosterone.

Protein hormones include those secreted by the pituitary gland--such as Follicle Stimulating Hormone, Thyroid Stimulating Hormone and Adrenocorticotrophic Hormone. The hormones of the gastrointestinal tract are also proteins. Peptide hormones (shorter than proteins) are formed by the hypothalamic nuclei of the brain and stored in the nerve ends of the neurohypohysis as oxytocin and pitressin.

3. The Glands of the Endocrine System in Human Beings

The anterior pituitary is located on a stalk at the base of the hypothalamus.

The posterior pituitary is an extension of the hypothalamus which stores neurohormones.

The intermediate lobe of the pituitary secretes a hormone which in lower vertebrates makes melanophores contract. The function of this hormone in man is not clear.

The thyroid gland is located on the trachea beneath the larynx. Its hormones are concerned with stimulating the metabolic rate and mental development.

The parathyroid gland consists of four small bodies embedded in the thyroid gland. The secretion of this gland helps mobilize calcium from bones for use in the control of body processes such as muscle contraction and blood clotting. The glands respond to blood calcium levels.

The Islets of Langerhands are embedded in the pancreas. They secrete two hormones, glucagon, which releases glucose from cells, especially those of the liver, and insulin, which is needed to transport glucose into muscle and connective tissue cells.

The adrenal glands (or suprarenal glands) are located just above the kidneys. The medullary part is a sympathetic ganglion, like those along the spinal cord, and secretes adrenalin and noradrenalin. The cortex secretes steroid hormones, aldosterone, cortisone, and about 25 others. No function is yet known for many of these substances.

The ovaries secrete eggs and also a number of steroid compounds concerned with regulation of the reproductive physiology of woman. Some of these are concerned with the full growth of the reproductive tract and effects upon the psyche related to mating. These are estradiol, estrone, and a third one secreted not by the ovary but by the placenta, estriol. Corpora lutea produce progesterone and some related steroids. This substance is needed for the maintenance of pregnancy and the development of the mammary glands.

The testes secrete spermatozoa and a number of steroid compounds concerned with the regulation of the reproductive physiology of man. Testosterone is the most abundant and most potent product. It is concerned with the development and maintenance of the male reproductive tract, and acts on the psyche to produce the protective behavior of males.

The duodenum is the site of release for secretin, the gall bladder contraction hormone and gastrin. Release is stimulated by acid from the stomach and halted by the alkaline secretion of the pancreas and of the bile.

4. Feedback Operation of Some Glands in the System

The hypothalamus of the brain form neurosecretions which affect the release of hormones by the anterior pituitary gland. The pituitary in turn releases Thyroid Stimulating Hormone (TSH) which acts to stimulate the thyroid gland to secrete thyroid hormone. This acts on tissues generally, but acts back on the hypothalamus which in turn decreases the release of TSH from the anterior pituitary gland.

ACTH from the anterior pituitary acts on the adrenal cortex to cause the synthesis and release of the cortical steroid hormones. These steroids act on the hypothalamus to cause a decrease in ACTH secretion by the pituitary. Since the secreted hormones of the gonads are also steroids, they too act to decrease ACTH release by the pituitary.

This kind of feed-back control exists also between the pituitary and the secretion of these hormones:

Pituitary hormone	Target gland secretion	Action on AP
FSH	Some primary follicles causing estrogen secretion	Depresses LH
LH	Converts Graafian follicle to corpus luteum	Depresses
LtH	Stimulates corpus luteum to secrete progesterone Causes "mothering" instinct	Progesterone depresses FSH
FSH	Stimulates spermatogenesis in the testes	
LH	Stimulates androgen secretion by the interstitial Leydig cells of the testes	Androgen causes storage of FSH

Hormones are effective in minute amounts. They act somewhat slowly, compared with nerves, but in a sustained way. It is a great principle in physiology that a constant environment causes a constant function. A change in the environment causes a change in function. The gene-hormone theory is that steroid hormones act to derepress gene cistrons but this has not been demonstrated to the satisfaction of many physiologists.

5. Mechanisms of Hormonal Reactions

Hormones affect the permeability of cell membranes, increasing the amount of materials available to the cell for growth and secretion.

Hormones may activate or suppress particular genes.

Estrogens have been shown to have a direct effect on some enzyme systems, but increasing the activity of these enzyme systems does not bring about the same effects as the estrogens.

Recent work shows that a wide variety of steroid and protein hormones activate cyclic AMP as a preliminary to bringing about their effects.

6. Interrelation Between the Endocrine and Nervous Systems

The nervous system is one of the first to become differentiated in the embryo. It is therefore not only the oldest system in the mammalian body but also the first to be organized by the notochord in the embryo. Nerves from the central nervous system pioneer to the myoblasts about the time they become able to contract. What happens is that the neurohumor secreted by the nerve modifies the environment of the muscle fiber at one spot, at the myoneural junction, on the contractile fiber. Whenever this happens, the fiber contracts. Smooth muscle responds to adrenaline more readily than to acetyl choline. Adrenalin works mainly by modifying the whole environment of muscle cells. Whether a small or a large part of the environment is changed, the muscle contracts. Therefore, nerves and hormones both act to modify the environment of their target cells, and whenever the environment is modified, the target cell "remembers" to respond.

Steroids are constant components of the lipid layer of cell membranes. It is not certain that a low cholesterol diet will lower cholesterol and cholesterolesters in the membrane. However, one aspect of steroid hormone action on target cells is to stimulate growth (see above). This may result in the increased membrane transport of sodium and potassium as a normal function (desoxycorticosterone and aldosterone). Since nerve function is the result of membrane transport of Na and K ions, these steroids may influence the ability of cell membranes, including those of neurons, to respond to stimuli.

There is a more easily seen effect upon the behavioral aspects produced by some hormones. Estrogens act on the nervous system to make courtship behavior possible. This does not mean that it determines such behavior in women since the brain has overriding restraints derived from the perception of the social situation. The same is true of the male hormones, which although they stimulate the acquisition and maintenance of mating territory and its protection and the protection of the included female(s), participation in courtship and mating is directed not by the hormones but by the perception of the social situation. In lower mammals the sex hormones have an almost overriding influence on courtship and mating. Luteotrophic hormone (LtH) is responsible for the mothering instinct from the fish upward. Cortisone, which causes deposition of circulating glucose as glycogen in liver, in large dosages can cause intense hunger in patients. Hunger is known to be a function of the hypothalamus, as shown by the destruction of parts of it experimentally.

The brain is the largest of the endocrine glands. If it were necessary to say that one gland was the master, the brain would probably be it, but it is recognized that the glands of the endocrine system do not master others, but establish feedback control from the level of secretion or release of responding glands.

Approach

Begin the section by doing Exercise 26--Response of Animals to Pregnancy Urine Hormone and setting up Exercise 37--Influence of Thyroid Hormone on Rate of Metamorphosis as a demonstration. Students should participate in the work involved. Also plant seeds for Exercise 28 if that has not previously been done for Unit 5--Genetics.

Show the film-loop "Hormonal Control of Behavior" Code number L.C. Fi A67-5662; color code 613673. This loop gives the history of early experiments leading to the discovery of the functions of hormones.

The class should be able to tell what the characteristics of a hormone are (but probably not "define" one). There is no definition of a hormone which characterizes it chemically or physiologically which is suitable as a general definition. If they cannot, rewind the film and show it again, this time telling them to write down words, ideas, etc. that they do not understand. Student questions based on these observations will be the basis of the discussion about the film.

If the students have read the specific reading assignment at the beginning of this section, then assign the reading of one or more of the following papers:

Berthold, A. A. (1848) Transplantation of the testes, in Gabriel and Fogel (eds.) 1955 Great Experiments in Biology. Englewood Cliffs, N. J. Prentice-Hall Inc. pp. 57-60.

Womack, E. B. and F. C. Koch. (1932) The testicular hormone content of human urine. Endocrinology, 6:273-277.

McGee, Lemuel Clyde. (1927) The effect of the injection of a lipoid fraction of bull testicle in capons. Proc. Institute of Medicine. 6: 242-244.

The paper assigned should be discussed afterward in class. This discussion can be used to introduce the class to the reading of a book like The Life of Christine Jorgenson.

For the second laboratory period (a week later) the class can treat the seedlings planted for Exercise 28 and spray the indicated groups with gibberellic acid. In this connection the film-loop "Regulation of Plant Development: Coleoptile Response in Zea" (Ealing No. 81-5134/1) can be viewed when the results have been collected and the class is trying to find an explanation for the results.

7. Phytohormones (Plant Hormones)

Specific Reference
Galston (1964) pp. 73-88

Alternate Reference
Simpson and Beck (1969) pp. 235-238

a. Auxins (Growth Stimulators)

Indole acetic acid and its analogues have the property of causing elongation in the near-meristem cells. They exhibit the "drug effect" so that large doses inhibit growth. A common broadleaf weed-killer, 2,4D (2,4 dicholorphenoxy acetic acid) is most effective after watering when growth is more rapid. The increased growth from 2,4D makes leaves and stems grow crookedly sometimes.

Auxin release is inhibited by light and stimulated by darkness. Plants placed in the dark grow rapidly, seeking the light. Phototropic plants bend toward the light because the shaded side grows faster.

b. Gibberellins (Gibberellic acid analogs)

These substances work in a different way from auxins to produce elongation of stems, derepresses genetic dwarfish, eliminates the need for vernalizing perrenials and increases the size of flowers and fruits. It stimulates flowering in long-day plants.

c. Kinetin (a Kinin)

Found in hydrolyzates of DNA. Acts with auxin to greatly increase mitosis.

d. Amo-1618, A Growth Inhibitor

One of a group of growth inhibitors like those on seeds and buds that prevent premature development in winter.

Approach

Do Exercise 28, if it has not already been done.

DISCUSSION QUESTIONS

1. Give the general characteristics of a hormone.

2. Name three hormones. Tell where they are produced, what their target organs are, and what effects they have on these organs.

3. What are the functions of thyroid hormone?

4. Do hormones effect the structures in which they are produced?

5. If you know the method of identifying a hormone, how could you determine whether a plant contains that hormone? (extract and test or inject tissue into organism sensitive to that hormone).

6. Fig. 1: A hormone in agar is placed on the tip of a plant with a cut stem.
   Fig. 2: A hormone is placed between two sections of a cut stem.
   Fig. 3: A hormone is placed on the tip of an intact stem.
   Light falls on all stems from the right.

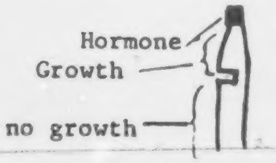


Fig. 1

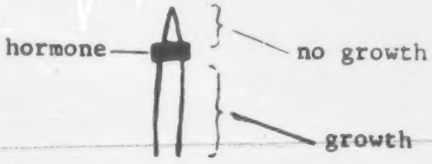


Fig. 2

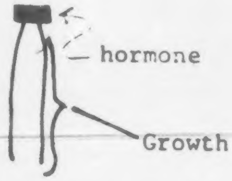


Fig. 3

What concepts of hormonal control could you give after analyzing these results? (Hormones are conducted down to target cells away from light, cells grow in area of concentrated hormones causing plant to bend toward light).
Explain the difference in the points of growth in the three figures. (No growth above the source of hormone).

7. Testosterone is placed externally on the comb of a baby chick. The comb grows large in two weeks.

   Testosterone is placed externally on the thigh of a baby chick. The comb does not grow large in two weeks.

   No testosterone is placed on the comb of the third chick. The comb does not grow large in two weeks.

   Testosterone is placed in the blood stream of the fourth chick. The comb grows large in two weeks. (This experiment was done using twenty-five chicks in each group). All other conditions were the same.

   a. Does testosterone cause the rapid growth of the comb? (Yes)
   b. Why doesn't the comb grow rapidly in the second and third group of chicks? (Possible local skin effect, hormone not in the blood).
   c. Give two ways in which testosterone can be transported. (Base all answers on observations cited.) (By diffusion into cells and by transport by the blood).

8. How could we prove that the intact target cell is not a prerequisite for hormone action? (Observe hormone in crushed cells.)

9. Hormones bound to blood proteins to a great extent. Would you be likely to find as much of the hormone in urine as you would find in blood? Why? Steroids usually appear as the glucuronide salt. Some proteins (HCG) normally filter through.)

10. Discuss the effects of thyroid on reproduction. What is its effect on growth and differentiation of tissues. (Delay sexual development, decrease lactation. See Turner Endocrinology for more extensive answer.)

11. In some instances hormones may react on several types of target organs or tissues. Give examples. (Pituitary acts on the gonads, adrenals, thyroid, connective tissues like bone, and the secretions of the glands in turn act back upon the pituitary gland.)

12. Can the nervous system, without the use of hormones, control body functions? (The nervous system secretes adrenalin, a hormone, but the endocrine target cells respond mainly to the sustained stimulation of chemicals (hormones) in a way that would exhaust the nervous system.)

13. Are there external discharges that can influence behavior and development in other organisms? (Yes. Queen bee has a mandibular gland that secretes a substance that inhibits the development of ovaries in worker bees. See Turner Endocrinology, page 10.)

14. Suggest some reasons why hormones affect a specific organ or organs, but do not effect all organs. (Specific active sites in organ proteins.)

15. What was the importance of the experiments of Bayliss and Starling 1902-1905? (They discovered secretin and thus established that chemicals help regulate body processes in addition to the control by the nervous system.)

16. It was originally proposed by Moore and Price that gonadal steroids in the blood acted directly upon the anterior pituitary to regulate the output of gonadotropins. This is a feed-back regulation. Discuss at least one feed-back regulation associated with the female human being's reproductive process. (Cite the effect of placental and adrenocortical steroid levels in the blood on the secretory activity of the pituitary gland.)

17. How could you determine the effect of a hormone which you could not isolate in pure form? (Remove specific glands.)

F. The Nervous System and Its Function

Specific Reference
Schmidt-Nielsen (1964) Chap. 7, pp. 92-102

Alternate References
Curtis (1968) pp. 332-341
Simpson and Beck (1969) pp. 238-244

Scientific American Offprints, Freeman & Co. San Francisco

#	
13	Gray. Oct. 1948
20	Katz. Nov. 1952
38	Snider. Aug. 1958
70	Loewenstein. Aug. 1960
98	Katz. Sept. 1961
99	Miller et al. Sept. 1961
174	Sperry. Jan. 1964
1001	Eccles. Jan. 1965
1038	Baker. March 1966

Teacher Reference
Katz, Bernard (1966) Nerve, Muscle and Synapse. New York. McGraw-Hill Book Co.

1. Introductory Remarks

Irritability is a normal characteristic of living cell membranes. This capacity to respond to stimuli (adaptability) ordinarily involves three principal components: (1) reception of a stimulus; (2) conduction of a signal; and (3) response by an effector. Much of the responding of plants to stimuli is dependent on variations in growth rates or changes in the turgidity of cells, both of which are inherently slow. On the other hand, all animal groups above the level of the sponges have some form of nervous system.

An organized nervous system is seen in its simplest form in Coelenterates of the hydra type, which show separate receptor, conductor, and effector cells. The conductor cells form a diffuse nerve net running throughout the body. There is apparently no central control of any sort. A more advanced condition can be seen in flatworms which have longitudinal cords and a primitive version of a brain which is concerned mainly with funneling impulses from the sense organs into the cords.

The Annelida and Arthropoda show a higher degree of centralization. In these animals the central nervous system consists of two ventral cords in which the cell bodies of neurons form a ganglionic mass in each body segment. The ganglia are connected by bundles of fibers running between the segments. The brain is just another ganglion in the head of these animals. It has some dominance over the other ganglia, but is limited in comparison with that of the vertebrate brain.

2. The Neuron and Its Parts

The functional unit of the nervous system is the nerve cell, or neuron. A typical neuron consists of a cell body, which has two or more processes extending from the cell body. Fibers leading from receptor cells are called sensory nerves, those leading to effector cells are called motor nerves, and neurons lying between the sensory and motor neurons are called association neurons. Neurons in a nervous pathway do not actually contact each other; the tiny separation between adjacent neurons is called a synapse.

The pattern of a reflex arc on one side of the spinal cord is shown in the following diagram:

3. The Central Nervous System

The brain and the spinal cord constitute the central nervous system. The highest center of the brain, cerebrum, is the seat of conscious perception, association and thinking. Localize functions of other parts such as thalamus, hypothalamus, cerebellum, medulla, olfactory lobes, etc. Let students locate the specific areas associated with sight, hearing, ability to speak, the movements of various parts of the body, etc.

Twelve pairs of nerves, called cranial nerves, leave the brain and lead to various parts of the head, except pair X, the Vagus (the vagabond). At the level of each vertebra, a set of spinal nerves leaves the spinal cord. These nerves supply all parts of the body; a motor impulse travels from the brain to the appropriate segment of the spinal cord and out through the motor nerves to the responding muscles.

4. The Autonomic Nervous System

This is the division of the nervous system which regulates involuntary muscular and glandular activity. The autonomic nervous system has two parts, the sympathetic and parasympathetic. Both may be distinguished anatomically from the central nervous system in that a relay of two or more neurons is required to complete an autonomic circuit. Neuron I leads from the central nervous system to a ganglion lying at some point outside the spinal cord or brain; neuron II picks up the impulse from the ganglion and carries it to the effector organ.

The sympathetic division makes use of adrenalin and noradrenalin as the neurohumor and produces these effects, often characterized as the "fight, flight and romance" syndrome:

Dilation of the pupils, bulging of the eyeballs, dilation of the nostrils, shallow breathing, sweating of the brow, dryness of the throat, shallow breathing, rapid beating of the heart, tenseness of the skeletal muscles, "tying up the guts in knots", a rise in blood sugar and in blood pressure. Cold fingers and toes also occur.

The parasympathetic system dominates after a good meal when one is relaxed by the fire. The syndrome consists of:

Constricted pupils, easy breathing, relaxation. Vegetative functions such as, urination, defecation, and sexual responses, are under the control of this system. (Note: Sex activity may be associated at times with the sympathetic syndrome, but after the excitement of romance passes--when "the honeymoon is over"--relationships are much more relaxed. Sometimes the uninformed think that when this happens that they are "no longer in love" and seek the excitement of a new romance.)

The viscera receive a nerve from both the sympathetic and parasympathetic system, and the activity of the organs reflects the relative amount of influence being exerted at the moment by each.

5. The Transmission of the Nerve Impulse

A nerve impulse can best be recognized by the electric changes in the nerve fiber over which the impulse is passing. If electronic amplifiers are applied to the area, the action potential of the fiber can be recorded. As a nerve impulse travels down the nerve, there are other changes such as heat production, consumption of oxygen, carbon dioxide production, movement of ions, and so on, but these cannot be measured as easily as can the electric changes.

All multicellular organisms must solve the problem of coordinating the activities of the different kinds of cells of which they are made. Two coordinating systems exist in most animals. One of these is the endocrine system which achieves control by the transport in the body or plant fluids of chemical substances, the hormones, which affect certain "target" or reception cells. The other is the animal nervous system. It consists of specialized cells, the neurons, which transmit electrical impulses from one part of the body to another. These two systems are not independent of one another. A close connection exists between their activities. Nervous coordination tends to be faster and generally more localized in its action. It enables the organism to respond quickly to changes in the external as well as the internal environment.

Approach for the Nervous System

Do Exercise 36 Reflex Action

(See Teacher's Guide to Exercise 36.)

DISCUSSION QUESTIONS

1. Describe the components and the arrangement of a reflex arc. Distinguish between nerve fibers and nerves.
2. Describe the organization of the central nervous system, its nerves, and its centers, What is a ganglion?
3. Describe the organization of the autonomic nervous system, its nerves, and its centers. What are the structural and functional differences between the sympathetic and parasympathetic systems?
4. What is a synapse? Explain transmission at the synapse.

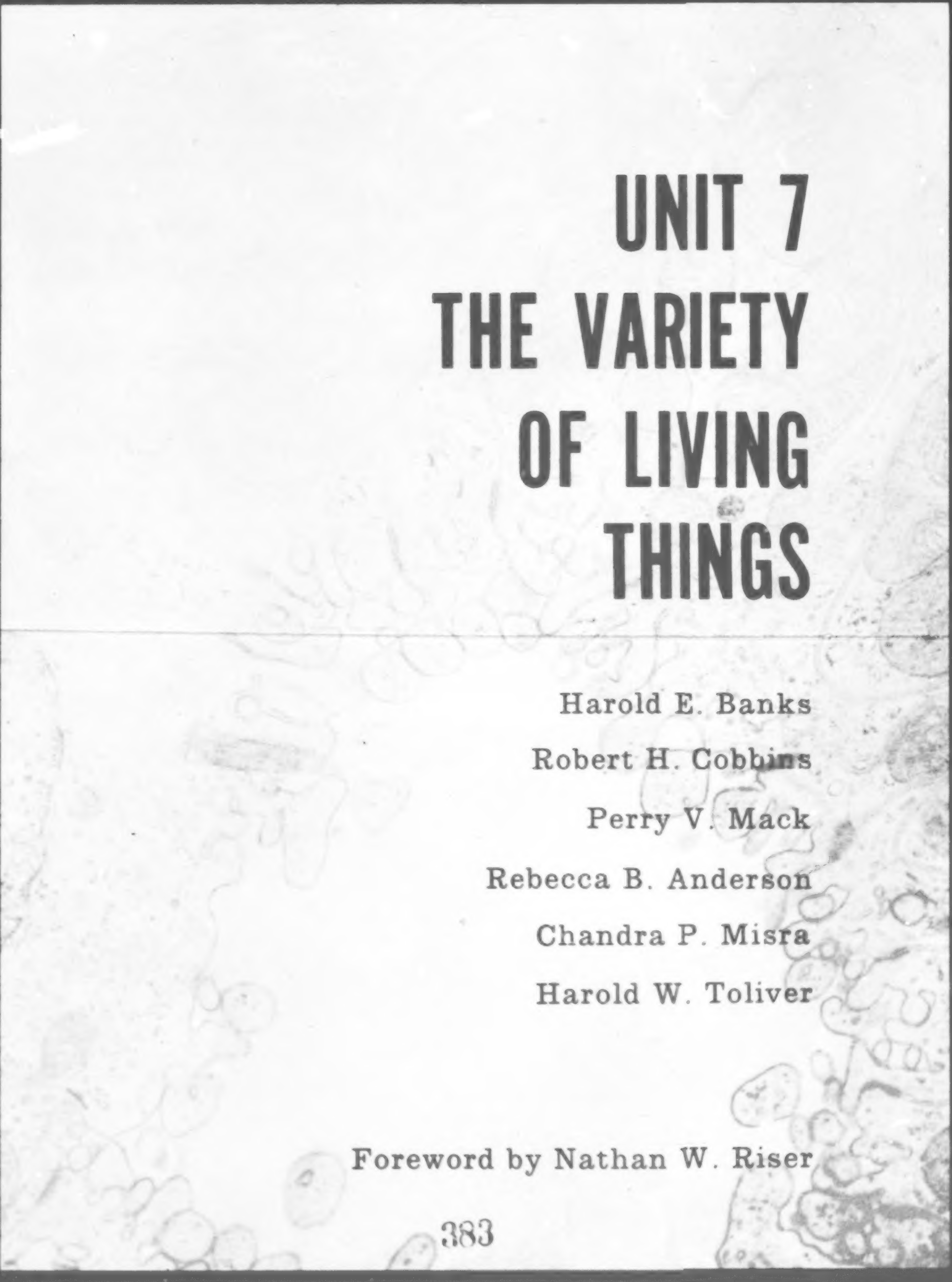
To reinforce the discussion do Exercise 36 in *Laboratory Activities for Biology*. (See the *Teacher's Guide to Laboratory Activities*)

Self-Tests

Self-test items on the specific reading assignment are listed in:

Humphrey, D. G., H. Van Dyke and D. L. Willis (1969) *Student Guide with Programmed Units* (for *Life*, shorter edition) New York. Harcourt, Brace & World, Inc. Chap. 11

UNIT 7
THE VARIETY OF LIVING THINGS



Harold E. Banks

Robert H. Cobbins

Perry V. Mack

Rebecca B. Anderson

Chandra P. Misra

Harold W. Toliver

Foreword by Nathan W. Riser

FOREWORD

It is the variety of living things that intrigues mankind but the classical approach to teaching this subject in Biology has destroyed the interest and curiosity of high school and college students. In this unit, an effort has been made to move away from rote-memory and to present organisms in their variety with emphasis upon life occupying all available living space and the means by which it has been able to attain this goal.

The principles of systematics and taxonomy are of worth, but the practice of systematics belongs to the systematist and the professional biologists in their various fields. To the educated human being, it is important to know that Mother Nature has tried many experiments, but no two the same way, and as a result, we find the great diversity of nature not in competition -- but always in a position to maintain life no matter what natural cataclysm might befall the earth.

Nathan W. Riser, Ph. D.
Director, Marine Science Institute
Northeastern University
Nahant and Boston, Mass.

INTRODUCTION

The emphasis in most biology courses today seems to be in the direction of molecular biology but it must be kept in mind that the molecular activity actually takes place in living organisms which have been formed from a primordial soup and continue to survive in an ever changing environment. This unit attempts to point out the variety of forms which have developed as a consequence of the trial and error activity of life in the environment through a great period of time. It also attempts to point up the fact that life forms are so varied as to assure the survival of life in some form even under extreme conditions.

The early schemes of classification are stages in the evolution of the modern systems of taxonomy. It shows how findings or works in other fields of science (e.g., use of computer in Numerical Taxonomy) influences our concept of taxonomy.

In considering modern systems of classification, the students should be led to an awareness of the fact that these systems are subjective and may be revised at various times even by the person devising the system. An effort should be made to show the deficiencies in the schemes.

Levels of morphological complexity should be approached in terms of the adaptive advantages of each succeeding level (see Unit 2--Evolution). There should be no great effort to memorize taxonomic ranks below class.

Progress Inventory

1. Differentiate between the following classification schemes:
   a. Linnean
   b. Phylogenetic
   c. Numerical

2. What is a Bryophyte?

3. Classify the following:
   a. amoeba
   b. lion
   c. elm
   d. oak
   e. moss
   f. elephant

4. Set up an animal classification system. What evidence did you use in setting up this system?

5. Draw a family tree which is consistent with the judgments you make in question 2.

6. What are the advantages of creating the kingdom of Protista?

7. The classification of living things has been agreed upon by biologists. True or false?

8. Some organisms can use inorganic molecules as a source of energy. True or false?

9. One of the most important processes to occur in the primitive seas was the conversion of inorganic compounds to organic compounds. True or false?

10. What is an animal? How can you distinguish animals from plants? Can all organisms be easily assigned to either plant or animal groups?

11. What is a worm? Do all worms belong to the same animal group? Why do you suppose the wormlike form is so popular?

12. How can you determine whether or not the differences that exist between two different animals are sufficient to put them into separate phyla? Classes? Order? Species?

13. Man and other vertebrates are the largest land animals. What are other types of animal life that compete most successfully with our group for life on the land? In what phyla are these types of animals?

14. All insects are arthropods, but not all anthropods are insects. Explain this statement.

15. List ten different kinds of animals that live in the sea or along the shore. Do you know what phyla they belong to?

16. What do man, cows, chickens, lizards, frogs and trout have in common that causes biologists to lump them into the same group -- the vertebrates?

17. What is
    a. phenon?
    b. species?

THE VARIETY OF LIVING THINGS

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Films

Diversity of Animals. "Nature of Diversity Pt. 1" AIBS Series

Contemporary Films (McGraw-Hill) #644602 Living Tide Pt. 3. The Edge of the Sea

Indiana University NSC-1003 Algae (specify color print)

How Life Begins (McGraw-Hill)

Ealing Film Loops

	#
Fresh Water Sponge	81-6801/1
Coelenterates	81-6744/1
Hydra	81-5761/1
Mollusks	81-6736/1
Segmented Worms	81-6751/1
Peripatus	81-5969/1
Millipede and Centipede	81-6769/1
Insects	81-6793/1
Echinoderms	81-5779/1
Asterias	81-6819/1
Arachnids	81-6777/1
Crustaceans	81-6785/1
Daphnia	81-6090/1
Flatworms	81-6728/1
Roundworms	81-7015/1
Carnivorous Plants	81-9706/1
Protists	81-5928/1
Gamete Dispersal in Mosses	
Gamete Dispersal in Liverworts	

TOPIC OUTLINE

I. Systems of Classification

  A. Dichotomy of Life

  B. Early Schemes
    1. Biblical
    2. Aristotle and his pupil Theophrastus
    3. Linneaus

  C. Modern Schemes
    1. Phylogenetic
      a. Homology
      b. Analogy
    2. Numerical Taxonomy
      a. Biochemical characters
      b. Antigenic characters
      c. Physiological characters
      d. Behavioral traits

II. Levels of Morphological Complexity

  A. Monera (Mychota)
    1. Protozoa
      a. Unicellular animals: Amoeba
      b. Advanced unicellular animals
        (1) True flagellates
        (2) Cilliates
        (3) Sporozoa
    2. Plants

  B. Protista

  C. Metazoa
    1. Lower Multicellular Animals
      a. Sponges
      b. Coelenterates
      c. Flatworms
      d. Annelids
      e. Mollusks
      f. Echinoderms
    2. Advanced Multicellular Animals
      a. Arthropods
      b. Chordates

  D. Metaphyta
    1. Bryophytes
    2. Tracheophytes

ANNOTATED OUTLINE

I. Systems of Classification

Specific References
    Simpson and Beck (1969) pp. 311-323
    Hanson (1961) pp. 10-25
    Dillon (1967) pp. 8-17

Alternate References
    Curtis (1968) pp. 245-303
    Kimball (1968) pp. 12-19
    Bold (1964) The first chapter compares three widely used but different systems of plant classification.

Teacher Reference
    Barkley (1967)

A. Dichotomy of Life

Life on this planet has evolved in two major directions. One of these lines leads to organisms, like trees, that can manufacture their own food from inorganic molecules like water, carbon dioxide and a few salts. This line is the one called the Plant Kingdom. The other line leads to organisms that cannot produce their own foods from the simple inorganic molecules, but, rather depend on the complex organic molecules from the other evolutionary line. They feed instead on the plants and develop a network of conductile fibers for coordination, and are able to move from one place to another, and constitute the Animal Kingdom.

However, among the microbes there are some organisms that can be classified as either plant or animal (Euglena). The plants and animals are basically the same biochemically except for the neuro-muscular system in the animals and the special photosynthetic apparatus of the plants. However, these differences are not as great as one might think because many of the biochemical steps (reactions) in respiration are like steps in photosynthesis, but in the opposite direction. The mechanisms of genetic replication are the same throughout the living world (see Chromosome Behavior in Unit 5). The differences between these producers (plants) and consumers (animals) become more profound at the multicellular level. The reasons for the variations or differences within the two major lines (not counting the microbes) have been discussed in Units 2 and 5. Thus, with such a distinct dichotomy in life forms, a system of identifying organisms individually and collectively with those closely related to them necessitated the establishment of the branch of biology called Taxonomy.

B. Early Schemes

1. The earliest recorded naming of organisms existed in the Bible. We don't know on what basis the organisms were named.

2. Aristotle and his pupil Theophrastus.
These men grouped the plants into trees, shrubs, and herbs. Beginning in the 16th Century it was realized that the most obvious characters of an organism aren't necessarily the most important.

3. Linneaus devised a system for classification according to the "sexual system". The plants were classified according to the number of stamens and carpels, their union, and their presence or absence in flowers. This system allows an interpolation of a new plant into these already established groupings. Linneaus was the first to use the binomial system of classification. During his time (due to the then current religious beliefs) species were regarded as fixed and unchanging. The presence or absence of some certain characteristics was used to determine into which group an organism was going to be placed.

C. Modern Schemes

The major difference between today's widely used systems and that of Linnaeus resides in our concept of what constitutes a species (See Unit 2--Evolution).

1. Phylogenetic

The binomial system of Linnaeus is the basis for the system of naming organism in use today, e.g., Homo sapiens, consisting of a genus and species name. The basis for phylogenetic types of classification is theoretical and mainly based upon:

a. Homology--fundamental anatomical similarity regardless of function (See Unit 2). The explanation of homology lies in the belief of common ancestry and thus the closer the evolutionary relationship the closer is the homology between two organisms.

b. Analogy--similarity of function, e.g., the wings of birds and a butterfly wing.

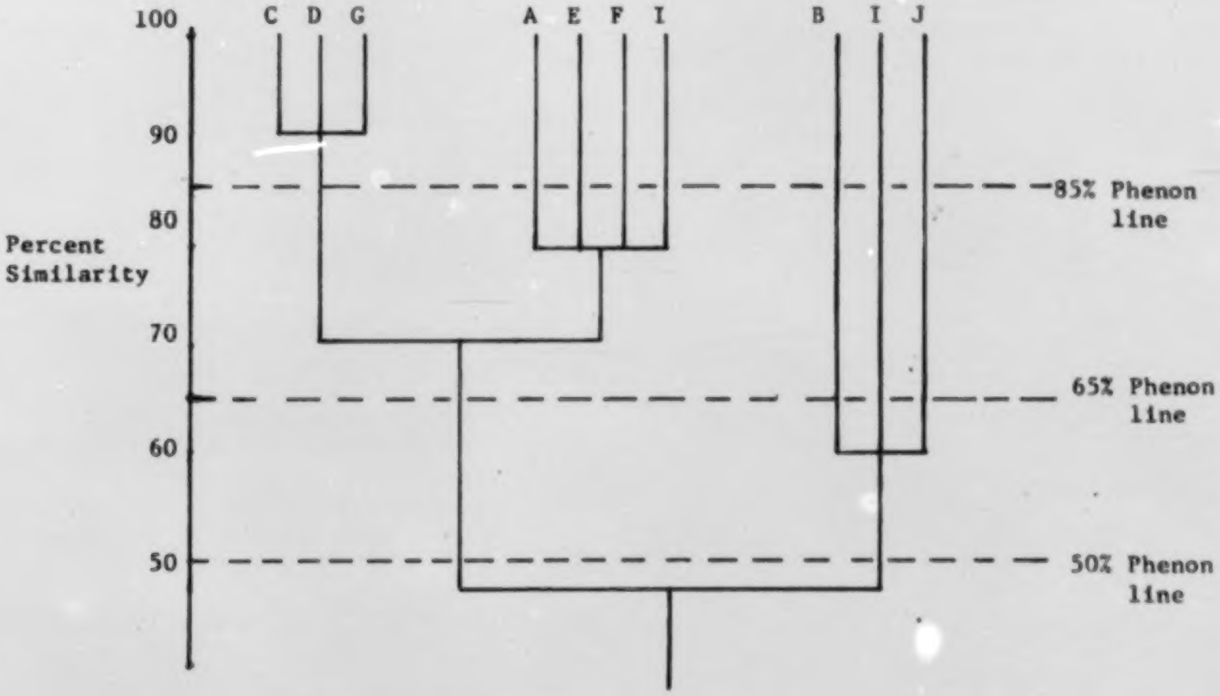
2. Numerical Taxonomy

This is the application of objective reproducible techniques for the quantitative mathematical expressions of degrees of similarity between organisms and groups of organisms.

Numerical taxonomy differs from phylogenetic taxonomy in the following ways:

	Phylogenetic	Numerical
1. Historic association with:	Darwin	Adanson
2. Conceptual basis:	Historical Phyletic	Static, phetic, empirical
3. Things studied:	Characters (1) measurable differences between organisms (2) have diagnostic significance	Features (1) any measurable trait (2) may or may not be diagnostically significant

	Phylogenetic	Numerical
4. Taxonomic values of traits assigned:	Unequal weights (weighted values)	Equal weights (each trait is 1 or 2 points)
5. Groups of organisms called:	Taxon, Species	Phenon, Pleiston
6. Nature of identified group:	Monothetic--all representatives of the group posses a common core of characters that distinguishes them from other organisms	Polythetic--groups of similar organisms in which not all representatives in the group possess every characteristic of the group, nor is any one trait always possessed by all members of the group


100
90
80
70
60
50
Percent Similarity
C
D
G
A
E
F
I
B
I
J
85% Phenon line
65% Phenon line
50% Phenon line

Hierarchical Arrangement of Strains

The following can be grouped under Numerical taxonomy:

a. Biochemical characters. Hybridization of the DNA or determination of the DNA base composition of organisms is made to see if they are similar.

b. Antigenic characters and protein-similarity, especially the blood proteins are determined. Proteins can be compared on the basis of their electrophetic behaviors, etc.

c. Physiological characters. For further discussion see Unit 2--Evolution.

d. Behavioral traits. This includes activities such as web making, mode of bird migration, etc. The programs for some of these traits are genetically determined.

Approach

The intention of this section of the unit is to expose students to some classification schemes for organisms. We will be chiefly concerned here with a comparative study of classification systems ranging from early efforts to group organisms to the modern schemes.

Classification schemes can be illustrated quite effectively by starting with familiar organisms. The class can learn that classification depends upon similarities and differences. Consider, for example, a collection of four organisms: a large plant, a small plant, a large animal, and a small animal. These can be lumped together in a category of living things. They can also be separated into two groups such as a group of plants and a group of animals. Within each group the similarity is emphasized, between the groups the differences are more important. Each group can then be subdivided on the basis of differences in size, or alternatively, the original group of four can be separated first on the basis of size.

Once the general principle is perceived, it can be applied to plants and animals. Students will realize that the ways in which certain organisms appear to be similar or different from one another helps in grouping them morphologically. They should be made to realize that each scheme has its strong and weak areas. They should realize that selection of any particular scheme by a biologist is not merely a matter of chance; each biologist chooses the approach that best seems to fit his data.

DISCUSSION QUESTIONS

1. What do you conceive to be the principal task of evolutionary classification?

2. Name the various fundamental features that may be used for the classification of organisms. Which of these has thus far proven most useful to the biologist? Why?

3. What changes have occurred in the principles and practice of classification since the many editions of Systema Naturae by Carolus Linnaeus in the 18th Century?

4. How does one determine that species possessing some features in common are actually related (of common descent)? How will you determine that an individual is a member of a particular species?

5. Discuss the advantages and disadvantages of Numerical Taxonomy.

II. Levels of Morphological Complexity

Specific References
Weisz (1965) pp. 129-200
Hanson (1961) pp. 71-105
Bell and Woodcook (1968) pp. 15-98, 103-184, 229-341
Dillon (1967) pp. 18-173
Simpson and Beck (1969) Chap. 15, 16, and 17

Alternate References
Galston (1964)
Sistrom (1962)
Jessop (1970)

There is a considerable diversity among the organisms of the world. We casually classify these organisms as animals, plants, microbes, invertebrates and vertebrates. However a closer look at this classification shows that it is an arbitrary one imposed for our convenience. The subkingdom Invertebrates is an example. There is nothing common to these groups of organisms except that they are composed of cells (like the Vertebrates). Some are jelly-like while others have an exoskeleton; some are morphologically simple while others are complex.

Some of the difficulties in taxonomy arise because the old and more established system of classification has no objective criteria by which to determine relationships. To start with, there are too many definitions of species, none of which is completely satisfactory.

A. Monera (Mychota)

These are cells without any definite nucleus but chromosomes are present. There is no definite nuclear membrane. There is, however, true sexuality and probably reduction divisions following fertilization. Included among this group are the bacteria-Schizophytes, Pseudomonales, Eubacteriales, Actinomycetales, Myxobacterioles, Spirochaetae (syphilis), and the Cyanophycae (blue-green algae), etc.

1. Protozoa - These are organisms containing a well-defined nucleus and a flexible cell membrane. They do not contain chlorophyll. They are actively motile, store food, principally as glycogen and fat. They obtain their energy from organic materials.

a. Unicellular animals: made up of one cell, referred to as protozoans, e.g., Amoeba.
Amoeba - This comparatively simple protozoan has no constant body shape and moves by protruding temporary Pseudopodia into which the cytoplasm flows.

b. Advanced unicellular animals - These protozoa show definite advanced adaptive development in structure and organization.
(1) True flagellates - protozoa whose movements are facilitated by activation of one or more whip-like flagella.

(2) Cilliates - Those protozoans possessing short, hair-like flagella on the surface of their bodies that beat in a regular fashion to move the organism or to trap food particles.

(3) Sporozoa - These protozoans include malaria and amebic dysentery pathogens. They lack special locomotary structures and move by changing body shapes. These are parasitic by nature and form resistant forms--spores.

2. Plants - Those organisms which possess a well defined nucleus, rigid cell walls and chlorophyll; which are not actively motile, store food principally as starch, and whose food is obtained by photosynthesis.

Algae (except the blue-green variety) - The simplest form of life that can be unquestionably classified as plant.

B. Protista

The organisms in this group possess a membrane-enclosed nucleus. Chromatin is present and nucleoli are seen. They exhibit mitotic and meiotic divisions. The presence of flagella is very common among this group and is usually tinsel or whiplash. Protists possess other cytoplasmic organelles like chloroplasts, etc. They are either saprophytic, photosynthetic, holozoic or symbiotic and are basically unicellular but some advanced groups are multicellular. There is a sexual process which involves the union of nuclear material followed by meiosis. In this group are the green, brown, and red algae, stoneworts, euglena, slime molds and the fungi among plants, and the protozoa among the animals.

C. Metazoa

1. Lower Multicellular Animals - Animals composed of many cells and grouped into Phyla (tribes) like the following:

a. Sponges - Animals composed of many cells that are not organized into tissues or organs. Although there is some cooperation among them, each lives an independent existence.

b. Coelenterates - Animals that are radially symmetrical throughout their life cycle. The animal is essentially a hollow container which may be vase or bowl shaped. The distinctive feature of the animal is the coelenteron (gastrovascular), a digestive cavity from which the group name is derived.

c. Flatworms - The bilateral symmetrical worm shaped animals with their elongated bodies have a precise dorsal and ventral surface. They have three distinct tissue layers; the ectoderm, mesoderm, and endoderm; a characteristic of all animals above the coelenterate level of organization.

d. Annelids - The body of these animals is segmented and consists of a linear series of homologous segments or metameres. The body contains a fluid-filled cavity, the coelom.

e. Mollusks - These animals may have one or more shells (valves) secreted by the underlying mantle, a muscular foot and a visceral hump housing the internal organs.

f. Echinoderms - An exclusively marine group of animals possessing spines that arise from calcareous endoskeleton of plates or ossicles lying just below the epidermis. The fact that they are radially symmetrical is believed to be a secondary development since the echinoderm is clearly a coelomate and the larval form is clearly bilateral.

2. Advanced Multicellular Animals - These groups of animals represent the most complex invertebrate and vertebrate life forms.

a. Arthropods - These animals are generally referred to as the "jointed-foot" animals. They are much the same in body plan throughout the entire group. They are segmented animals having an exoskeleton which is secreted by the animals' epidermal cells.

b. Chordates - These animals are distinguished from other animals by the possession, during some part of their life history, of three unique characteristics: (1) a flexible supportive rod (the notochord); (2) a hollow nerve tube running dorsal to the notocord; and (3) a paired series of pharyngeal clefts running along each side of the throat.

D. Metaphyta

This group includes the green terrestrial multicellular plants. They possess chlorophylls a and b, cell walls made of ceullose and deposit starch for food storage. These characteristics are also found among the algae (Protista) raising the possibility of green algae being the ancestors of higher plants. They differ from the algae because they possess organs, have a distinct alternation of generations, and have a high ratio of volume to surface area. The presence of cuticle, vascular tissue, and the high volume to surface area ratio favor their survival on land.

Two major groups constitute the Metaphyta -- the Bryophytes (mosses and worts) and the Tracheophytes (vascular plants).

1. Bryophytes - They are widely distributed all over the world as liverworts, hornworts and mosses. The plant body in liverworts and hornworts has dorsiventral symmetry while the mosses have radial symmetry. Economically they are used for retarding soil erosion.

2. Tracheophytes - These constitute all the higher plants like trees, shrubs, etc. They represent the largest group of photosynthetic organisms and they are characterized by their vascular tissues - xylem and phloem. The body is subdivided into roots, stems and leaves, each of which is a true organ.

Approach

Show Ealing film loops on Amoeba, Paramecium, Euglena, Stentor, Vorticella, Blepharisma, Volvox, Stylonychia, Chlamydamonas, Gyrodinium, and other Protists. Establish through discussion that there is a variety of organisms at the unicellular level. See if they notice that some forms are structurally more complex than others, thereby establishing early that there are complex unicellular forms of protozoa. Encourage them to observe morphological similarities between the forms shown and also to establish a range of size for these organisms. Call attention to methods of locomotion and behavioral responses.

By this time the student should be able to identify, at a glance, several different types of Protozoa. Have some cultures from pond water available to see if the students are able to identify specific unicellular organisms. Note also other forms which may not be unicellular. The film loops, slides, live cultures and other available resources may be used as references in the establishment of identification patterns. Recognition, on the other hand, should result from knowledge acquired by the individual student.

Do Exercise 17--The Phyla of the Animal and Plant Kingdoms (See Teacher's Guide to Exercise 17).

DISCUSSION QUESTIONS

1. Distinguish between homologous and analogous organs. Why can the former but not the latter be used as criteria in classification?

2. What are the chief characteristics of the protozoa?

3. Compare the methods of movement and nutrition in Euglena, Paramecium and Amoeba.

4. List the arguments for classifying Euglena as an animal, as a plant, and as a protist.

5. How do sponges obtain food and water?

6. Compare the alternation of generations exhibited by animals or plants studied in the laboratory.

7. An animal is multicellular, has no digestive system, and its body is perforated with pores. What is it?

Self-Test on Classification

Multiple choice. Select the one best response.

1. Carolus Linnaeus, 18th Century naturalist, viewed species as
    a. having evolved, one from another, in the long history of life.
    b. a population of individuals of common descent.
    c. fixed, unchanging units of divine creation.
    d. changing units in continual flux.
    e. an abstraction of the statistical measurement of a group.

2. Organisms may be classified (placed into groups or categories) on the basis of
    a. ways of living.
    b. habitat (places of living).
    c. anatomy and physiology.
    d. all of the above.
    e. none of the above.

3. Classification of organisms on the basis of comparative study of form and function includes the
   a. analysis of degrees of resemblance.
   b. selection and interpretation of anatomical and physiological characters.
   c. determination of the abstract type or archtype of each group.
   d. both a and b.
   e. both b and c.

4. In contrast with the Linnaean view of organisms, the contemporary practice of classification includes consideration of the variations within a species by the utilization of
   a. a population approach or concept.
   b. a typological approach or concept.
   c. fossils, as well as living organisms.
   d. analogous structures.
   e. homologous structures.

5. The best and the only direct evidence that an individual belongs to a particular species is
   a. its anatomical similarities as determined by laboratory study.
   b. its physiological similarities as determined by laboratory study.
   c. its living with a population of the species and its functioning within the population.
   d. both a and b.
   e. both b and c.

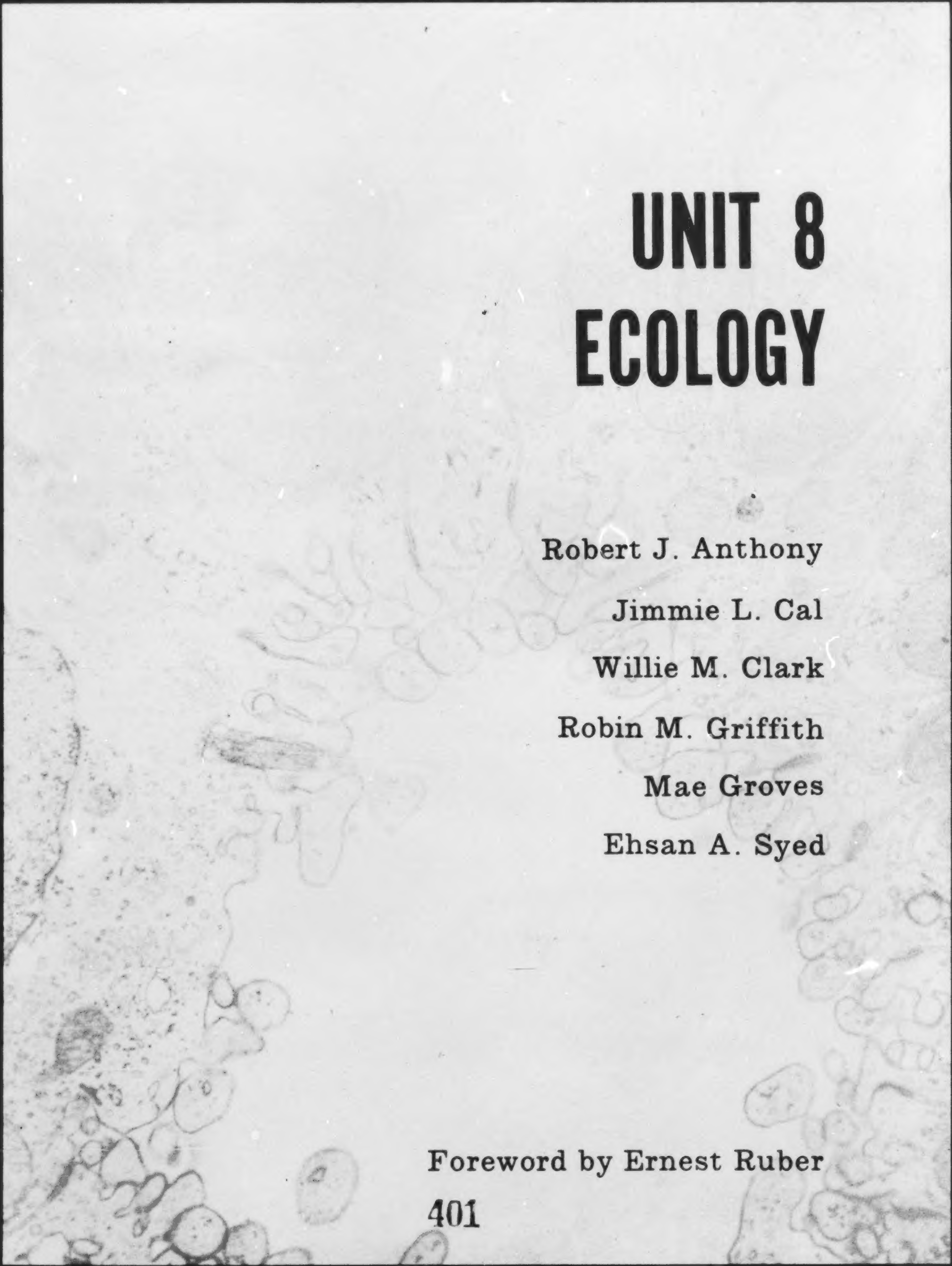
True or False: Consider the following statements carefully. Mark them as being either true or false.

6. Contemporary human beings are classified as 6 to 8 different species.
7. The species is the fundamental population unit of classification.
8. To sample a population is to take one or two individuals as representative of the group.
9. The characteristics of a species are now determined (or evaluated) by statistical procedures of study.
10. Schemes of biological classification include a hierarchical arrangement of the various groups developed to accommodate the organisms studied.
11. Species are unchanging units of life.

Match. For each item in the left hand column choose all of the items in the right hand column which apply. For each numbered item, more than one letter choice may be made.

12. Homology
13. Homoplasy
14. Analogy
15. Convergence
16. Divergence
17. Transformation

a. structural correspondence
b. functional correspondence
c. structural and functional correspondence
d. same or common ancestry
e. different ancestry
f. a process
g. an interpretation of the result of a process



UNIT 8
ECOLOGY

Robert J. Anthony

Jimmie L. Cal

Willie M. Clark

Robin M. Griffith

Mae Groves

Ehsan A. Syed

Foreword by Ernest Ruber

FOREWORD

Ecology is a discipline which until fairly recently was not regarded by most biologists as an important area of study. This was in part due to the great complexity of the subject matter which could only be approached at such levels as the "Law of Minimum."

During the last thirty or forty years, the discipline has developed strongly on two fronts. The first of these is the study of populations and the second the study of ecosystems. These two areas gave to the ecologists a series of new integrating concepts which could be used to expand our understanding of the interaction of the organism with its environment. The development of these newer areas in ecological thought coincided with another set of circumstances - the accelerating degradation of our available land, the fouling of our waters, the careless depredations on our nonrenewable resources, in brief, the impact of modern industrial man in great and careless numbers on his environment. The combined factors have led to an enormous increase in the interest of citizen and biologist in this discipline. We are suddenly asking the ecologist to evaluate the consequences of our activities. Unfortunately for ourselves our questions come late and the degree of our commitment to salvaging our environment is not yet very rigorous when measured in dollars.

It is this realization that has caused many departments of biology to institute requirements for an ecology course for their majors. It is no less important for non-majors to be exposed to these concepts. The only hope for a decent environment for the generations of our species to come is in the education of our citizens in these concepts which should lead to the realization that we are a dependent part of the environment of our planet, that we will continue forever to be so dependent and that we must, as a species, begin to act as though we knew these facts.

Ernest Ruber, Ph.D.
Associate Professor of Biology
Northeastern University

INTRODUCTION

Ecology is a classical area of study in biology and has always been important in its own right. However, following the 1968 national elections, young people of the United States, full of energy and idealism, took ecology and the quality of the environment as their "cause". Biologists and educators who have been warning the public about the ecology of the country for years, as well as conservationists, who have not only led the way for the reforestation of burned over areas of woodlands, brought contour ploughing to the farmlands, and urged Federal reserves of oil and water, were skeptical. Was this going to be another fad like crowding into telephone booths or smashing pianos? Fortunately, public leaders, including the Congress and the President of the United States, gave ear. Now Ecology is a household word in America, the government has an environmental control agency, and environmental education is a definite program in the Department of Health, Education and Welfare.

This unit is divided into four sections. The first section deals with the community and ecosystem level of organization. The effort here is to have the student become aware of the structures (or at least of the non-random character) of the organization of biotic communities. The section is introduced with a trip into the field to observe first-hand something of the organization of plants (and some animals) in communal associations. Then comes a discussion of the components of an ecosystem and a consideration of ecological succession. The section ends with a description of the different kinds of terrestrial and aquatic biomes.

The second section deals with the physical and chemical components of the environment and the ways that these interact with organisms. The water, carbon and nitrogen cycles are introduced here for discussion. Physical factors such as light, heat, etc., and of chemical factors such as salinity, acidity, nutrients and wastes are also considered with regard to their effect on animals.

Section three has two main parts. First, there is population ecology, in which the effects of numbers of the same species in a given delimited locale is considered. The second subsection deals with species interrelationships such as mutualism, parasitism, predation and competition. The accent here is on the way in which many of these relationships define the habitats and conditions under which the various members live.

The final section of the unit addresses itself to the complex problems involved in the deterioration of the environmental quality as far as human beings are affected. The concern here is development of student sensitivity to the way man, in his interactions with nature, has caused serious damage to the natural systems which support his well-being and survival. To illustrate the extent of the damage, air and water pollution are studied in some detail. The relevance of these issues should be clear and the student is encouraged to see the problem in the light of its effects on his city, neighborhood, home and on himself personally. The student should thus be armed with the knowledge, perspective and sense of responsibility to actively participate with the growing ranks of people concerned with pollution control.

This unit has been written in such a way as to make it fit into a three-week time span in a sort of reasonable way. The greatest difficulty has been contriving suitable laboratory experiences because of the limitations of time and location. The laboratory activities include field trips to areas available to most schools in one way or another.

The objectives sought in teaching this unit are:

Development of an awareness of the importance of environmental factors affecting the various species.

Development of awareness of some ecological principles, as for example the Law of Minimum and the Law of Tolerance.

Ability to extrapolate from specific local examples to major distribution patterns of plants and animals, and some of the factors affecting this distribution.

Understanding the manner in which the special characteristics of a population affects the capacity of that population to exist in a given environment.

Developing an awareness of the interaction between organisms in a community, and especially the interactions of other living things with man.

Understanding ways in which interactions between a species and its environment will affect the distribution of the species concerned.

Becoming aware of the types of communities, their structured character, and the directional changes we call succession.

Making the student sensitive to the need to clean up and maintain a relatively pollution-free environment.

Development in the student of a concern for the public and private responsibilities for pollution control.

ECOLOGY

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Scientific American. September, 1970. Vol. 223(3)

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TOPIC OUTLINE

- I. Community and Ecosystem: No Organism Is An Island
  - A. Components of an Ecosystem
  - B. Ecological Succession
  - C. Major Ecosystems

    - 1. Ecological Principal Concepts
    - 2. Terrestrial Biomes
      - a. Tundra
      - b. Coniferous Forest
      - c. Temperate Deciduous Forest
      - d. Tropical Forest
      - e. Grasslands
      - f. Deserts
    - 3. Types of Freshwater Environment
    - 4. Marine Environment

- II. The Physical and Chemical Environment
  - A. Internal and External Environmental Effects on Organisms
  - B. Effects of the Physical Environment
  - C. Effects of the Chemical Environment

- III. Species and the Biotic Environment
  - A. Population Ecology
    - 1. Density
    - 2. Natality
    - 3. Mortality
    - 4. Age Distribution

  - B. Co-action and Special Species Interaction
    - 1. Commensalism
    - 2. Mutualism
    - 3. Parasitism
    - 4. Competition
    - 5. Predation

IV. Pollution

- A. Objectives and Introduction
- B. Approaches
- C. Types of Pollution

  1. Air pollution

     a. Smoke
     b. Radiation
     c. Insecticides

  2. Water pollution

     a. Detergents
     b. Raw Sewage
     c. Oil Pollution

  3. Other ways man has affected his environment

     a. Animal Extinction
     b. Exploitation of Natural Resources
     c. Overuse and Misuse of Open Spaces

- D. Pollution Control

Films

From McGraw-Hill Films, 330 West 42nd Street, New York, N. Y. 10036

(1) The Changing Forest (Canada), 30 min., Color, produced by the National Board of Canada.

(2) Energy Relations (Color-Code 613316), 28 min., Color, produced by McGraw-Hill Films.

(3) World in a Marsh (Canada), 30 min., Color, produced by the National Board of Canada.

Population Ecology (1967), 19 min., Color, produced by Encyclopedia Britannica Corporation. Sale and Rental Agency Encyclopedia Britannica, 425 North Michigan Avenue, Chicago, Illinois 60611

The High Artic Biome, 45 min., Color. Sales and Rental Agency Encyclopedia Britannica.

Film-Loops

1. Cat. No. 81-3246 Marine Predators: Competition for Food.
2. Cat. No. 81-6850 Plankton: Food Webs and Feeding Relationships.

Source: Ealing Film-Loops, 2225 Massachusetts Ave., Cambridge, Mass. 02140

ANNOTATED OUTLINE

I. Community and Ecosystem: No Organism Is An Island

Specific Reference: Buchsbaum and Buchsbaum (1964), pp. 59-97

Alternate References: Odum, Eugene (1966), Chap. 2, pp. 7-36
Kormondy, E. J. (1969), pp. 115-154

Approach

Carry out the field trip for Exercise 38 as outlined in the Teacher's Guide to L.A.B. before beginning the discussion of this section.

Also, at least a week beforehand, set up a closed aquarium as an example of a miniature community or miniature biome for use in the classroom by filling a three-gallon bottle about one-half full of pond water. Add 8 or 10 ounces of soil and a small amount of algae from a pond. When the material has settled and the water is clear, add four or five sprigs of Elodea. Then introduce several guppies or other small fish, a snail or two, and a piece of clam shell to neutralize acid wastes. Cork the bottle so that it is airtight. Set the corked bottle in a well-lighted place in the classroom, but not in direct sunlight. The temperature should not rise above 70°F. The living things in this sealed bottle may live and grow for months because there is a natural balance between the carbon dioxide given off by the fish and used by the plants, and the oxygen generated during photosynthesis in the plants is used by the animals. Using this balanced aquarium as a model of a community or miniature biome one may begin by presenting it to the class as an object for discussion.

Ask the students to comment on the various features of the aquarium--its contents, where the food comes from, how can the living things get along without additional air, and so forth. List the things suggested on the chalkboard.

Next draw parallels between the miniature community in the bottle and the natural-sized community visited by the class for Exercise 38 (or Ex. 39 if that one has also been done). Hold up several specimens, one at a time, and have students who collected them comment on the kind of habitat the specimen came from.

From the data supplied by student discussion of the field trip, diagram on the blackboard the food chain detected in nature and the one taking place in the sealed bottle.

Next ask students to formulate their definitions or partial definitions for these terms: Community, biome, ecosystem, niche.

Show a movie from the list on page 8-7.

Discussion Questions

1. What are the conditions necessary for an ecosystem?
2. What are the characteristics of a forest community? A grassland community? A desert community?
3. In what ways are certain environmental conditions in the oceans more stable than the corresponding conditions on land?
4. How does a decidous forest differ from a tropical rain forest?
5. How does the food web in the surface waters of the open sea resemble the food web on land?
6. Which of the major land environments more nearly approaches the the degree of stability of conditions in the oceans?

GENERAL ASPECTS OF PLANNING A FIELD TRIP

by Robert J. Anthony
Jackson State Univ.

I. Definitions

A. A field trip is a planned visit to a point outside the regular classroom setting.

B. The field trip is a going-out process in which students study the work-a-day world operation.

C. It is a process of using the field (outside source) as a classroom activity.

D. It is a way of connecting the theory of the classroom to the practice of life itself.

II. Objectives

A. To make learning more meaningful to the students.

B. To provide experiences by which students' learning may become full and well-rounded.

III. Procedures

A. Field trip should be well planned by the teacher and students.

B. The teacher should visit and be well-informed about the place he is going to take his students.

C. The purpose of the field trip should be clearly understood by the student. This might embrace preparing some type of handout related to the trip. If possible arouse student interest by giving thought-provoking questions as handout or use other means.

D. Field trip should be as informal as possible. Clear-cut purposes should dictate discipline.

E. See the field trip as an educational tool to increase the information and understanding of students.

F. Plan for good record keeping for yourself and the students.

G. Make sure that your follow-up is well planned. This may be done through:

1. Group discussion
2. Group or individual creative projects
3. Test to determine information gained, attitudes formed and generalizations made

ORGANIZATION OF A ONE-DAY FIELD TRIP

by Elizabeth D. Clark
North Carolina A. and T. State Univ.

1. Choose a Saturday when students will not have to miss another class.

2. Decide on the location and the best date for the class to visit the area and see what the teacher wishes to emphasize.

3. If possible, obtain some geological history of the place. This is available for most state parks.

4. Before the scheduled field trip, map out the area to show locations of specific types of land formation and biomes (bog, lake, field, beach, alpine meadow or other features)

5. Check the trails to see what size group can best pass safely and how much climbing and walking are involved. People, who cannot climb or walk a lot because of physical disabilities, should not be required to do so.

6. Each trip should have a section planned so that those not able to climb can have a complete experience in discovering concepts of the community, the interaction of physical, chemical and biotic environments to create an ecosystem.

7. Books on the identification of plants and animals add a lot of interest; but the study of what is required for the organism to be able to exist in this environment, also what advantages are offered by the environment for the survival of the plant--should be emphasized. General relationships are more easily remembered than names of organisms.

8. For information on natural areas in your vicinity, consult the U. S. Department of Agriculture, The Nature Conservancy Organization, your State Forestry or State Park Authorities.

9. Travel by bus or car should be arranged with the understanding that the trip can only be made in fair weather.

10. With large groups it is difficult to start very early and have breakfast on the way unless previous arrangements have been made. Students can eat an early breakfast (7:00 a.m.) so that they can reach their destination and make the Ecological Study from 10:00 to 12:00 noon and from 2:00 to 4:00 p.m.

11. Lunches should be carried unless arrangements have been made in the area visited. The students can return to campus and have supper there.

12. It is helpful to pass out maps of the area, a reprint of the geological history and a list of terminology that may be used. En route to the area or the day before, have students discuss the community in which they live and, in doing so, develop the meanings of most of the terminology.

13. While on the bus make a list of all participants and account for each before returning home. Check off all names of persons returning by means other than the bus.

14. Divide the students according to their interest and ability to climb or walk long distances.

15. If possible make slides or movies of the students in many learning situations and use these in later discussions.

16. Since students may be under different leaders, it is advisable to have a discussion of the field trip--preferably in a seminar type situation where all of the students are present at the same time. Choose a panel of students to lead the discussion. I usually wait for a week so that I will have all slides developed for use during the discussion.

17. Invite former students to contribute slides and pictures of interest. These often show the same areas in different seasons. Frequently the former students come in to join the discussion of ecology.

18. If two different schools are near such as Bennett College and A. and T. State University, or if two schools are in the same state and plan a trip together--the joint field trip offers an opportunity for intra-collegiate relationship between the students and faculty of the two schools which is very stimulating and beneficial. The groups are mixed and the students have the advantage of the discussions from the two faculties.

19. Ask the biology, physical science and other interested teachers, who are not in our program, to participate and help plan the trip. Our director and counselor always go on the trip. Try to have one instructor for every 10 to 20 students.

20. It is necessary to carry field glasses since most animals are best seen at a distance. They usually hide. Hand lenses and microscopes make possible the study of organisms which are not to be collected and brought into the lab.

21. Do not forget to carry collecting apparatus, pencils and paper for recording data.

22. Dress for comfort and protection from insects, from scratches in areas of thickly-grown plants and from water in bogs or streams.

A. Components of an Ecosystem

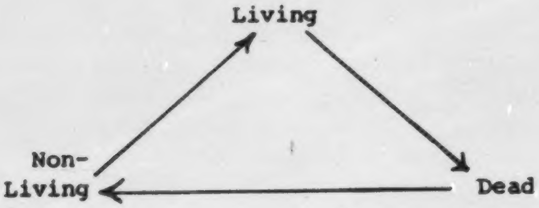
Specific References:
Scientific American, September 1970, Vol. 223(3), pp. 44-53
Buchsbaum and Buchsbaum (1962), Chap. 2, p. 21

Alternate References:
Odum, Eugene (1966), Chap. 2, pp. 25-36
Kormondy, E. J. (1969), Chap. 1, 2 and 3, pp. 1-61

Approach

Carry out the field trip for Exercise 39 as outlined in the Teacher's Guide to L.A.B. before beginning the discussion of this section.

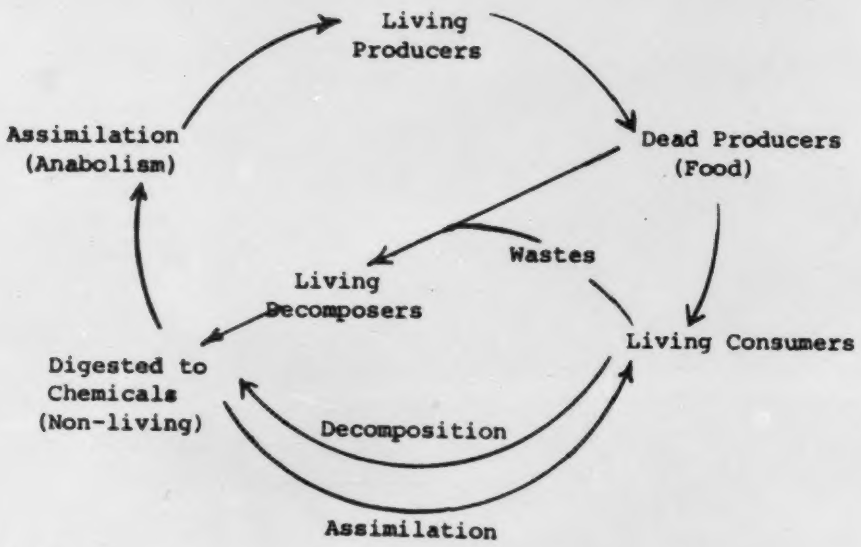
Begin the discussion session by placing the following diagram on the chalkboard:



When life leaves living things they are dead. Dead things become decomposed to chemicals which lack the appearance of living or once-alive structures. These chemicals are usually referred to as non-living. Digestion is the usual way in which dead things become broken up into that which is non-alive. The non-living chemicals are then assimilated into living material.

The four main components comprising an ecosystem are:
- abiotic substances (non-living and dead)
- producers (living)
- consumers (living)
- decomposers (living)

The relationships can be diagrammed as follows:


Living Producers
Dead Producers (Food)
Living Consumers
Wastes
Living Decomposers
Decomposition
Assimilation
Digested to Chemicals (Non-living)
Assimilation (Anabolism)

B. Ecological Succession

Specific Reference:
Buchsbaum and Buchsbaum (1962), Chap. 6., pp. 98-128

Alternate References:
Odum, E. (1966), Chap. 6, pp. 77-89
Kormondy, E. J. (1969), Chap. 5., pp. 14, 154-165

Approach

Before beginning this discussion carry out the field trips in Exercise 39 according to the Teacher's Guide to L.A.B.

Ecological succession is the orderly process of community change, in which one community replaces another until a stable one, the climax community, is reached. (See Exercise 39 and Teacher's Guide to L.A.B.)

While on the field trip, one or more groups can collect some dry grass or leaves from near a pond or pool. As an added laboratory activity, have each student group start an hay infusion culture.

Use distilled water or boiled pond or tap water. (Boiling drives off excess chlorine and carbon dioxide)
Add a few sprigs of grass to about 50 ml. of water in a flask or jar. An adequate air space above the culture is needed for a final balance of protozoa over bacteria.
Place in a warm (65-75°F.), lighted place, but not in sunlight.
Have students examine a drop of water at the start (after the grass has been added, and every day or so after that for a week, recording a qualitative evaluation (0, +, ++, +++, ++++) for each kind of living organism seen on each day the culture is examined.
After a week discuss the kinds of observations members of the class will report.
Collect the reports and mark them A, S, or I.

Self-Test on Community Ecosystems

Source: Humphrey, Van Dyke and Willis, 1967, Student Guide with Programmed Units for Life, pp. 186-187

1. All food chains end with predators? (True or False)
2. Pyramids of mass, number, and energy depict food chain or food web relationships? (True or False)
3. The climax community of a region is usually a forest? (True or False)
4. The energy flow in natural communities normally ends with the activity of decay organisms? (True or False)
5. When two species of plants or animals compete for the same environmental requirements, both species are usually so weakened by the competition that they are both eliminated in favor of a more fit species? (True or False)
6. Which one of the following could be regarded as the most constant major environment?
   a. the rocky seashore
   b. the dense litter or the floor of a temperate forest
   c. a fresh-water lake
   d. the deep sea bottom
   e. a mountain peak above timber line
   f. a very sandy desert
7. Competition between different species of animals usually focuses on?
   a. shelter
   b. food
   c. status
   d. choice of mate
   e. water
   f. protection of young
8. Which of these pyramid relationships is a direct illustration of the second law of thermodynamics?
   a. pyramid of mass
   b. pyramid of energy
   c. pyramid of numbers
   d. all of the above
   e. none of the above

Answers

1. false
2. true
3. false
4. true
5. false
6. d
7. b
8. b

C. Major Ecosystems

Specific References:
Odum, E. P. (1963), pp. 7-36
Buchsbaum and Buchsbaum (1967), pp.

General Introduction

The interplay of physical and biological forces has resulted in the establishment of characteristic groups of plants and animals in all habitat areas of the world.

The plants and animals living in any natural area form an assemblage in which each individual finds the environment to be tolerable and to provide at least the minimum requirements. They become mutually adjusted and form what is known as a community.

Community concept has both a functional and descriptive aspect. Functionally it is the interrelations of the variety of organisms in its environment. The descriptive aspect is characterized by having a definite species composition.

Communities of plants and animals vary over the surface of the earth largely in relation to climatic differences. The same general types of producers and consumers appear together in similar climatic zones.

1. Principal Ecological Concepts

Major terrestrial ecosystems (biomes) are characterized by distinctive biotic composition and are usually named for the dominant plants.

Distribution patterns are determined largely by solar radiation, water precipitation and temperature.

The same basic ecosystem concepts of structure and function apply to both aquatic and terrestrial environments despite their different physical and chemical compositions.

2. Terrestrial Biomes

Communities whose dominant components (species) have become more or less permanently established in certain climatic regions of the world will attain the climax condition. The concept of "climax" suggests a rather stable community. Ecologists recognize a limited number of major climax formations called biomes.

Terrestrial ecosystems are classified on the basis of their biotic components and are named according to their dominant plant forms. Six of these are considered here.

a. Tundra - (north of the timberline) The northernmost biome of North America, Europe and Asia. It corresponds roughly to the region where subsoil is permanently frozen. The climate is cold with a growing season of about 60 days.

Fauna - Reptiles and rodents are the most characteristic animal life. Most live underground or in shaded nooks.

3. Types of Freshwater Environment

   a. The flowing-water community
   b. A standing-water community

4. Marine Environment

   The ocean is the most extensive of all habitats. More than two-thirds of the surface of the earth is covered by the oceans. The oceans are teeming with life:

   a. Nekton - Plants and animals on the ocean floor or bottom-dwelling. (limited swimming ability)
   b. Plankton - At or near the surface.

II. The Physical and Chemical Environment

Do Exercises 39 and 40—Effect of Chemical and Physical Factors on Animals before beginning this discussion.

Specific Reference:

Buchsbaum and Buchsbaum (1964), Chap. 2

Alternate References:

Knight, Clifford B. (1968), Chapter IV and V
Odum, E. P. (1969), pp.

A. Internal and External Environmental Effects on Organisms

1. The cell, the only container of life, arose in the sea. Its predecessor, the pre-cell, was without membranes and its components were in direct contact with the environment. In fact, there was no "inside" nor "outside" so that the environment pervaded the pre-cell and the pre-cell was, therefore, part of the environment.

2. The development of the plasma (cell) membrane separated the "inside" somewhat from the "outside", but even so, the environment of the molecules making up the living stuff had to remain very much like the former outside. Too great variations in temperature, salinity, pH, or radiation would result in the denaturation of the proteins and an interruption of the metabolic processes. Exercise 40 demonstrates these effects.

3. When a living membrane is stimulated, there is a reversal of its ion pump so that instead of K^+ ions being in high concentration on the inside of the membrane, Na^+ ions are high and potassium ions are in low concentration. That is, during an impulse, the ionic relationships on the two sides of the membrane are reversed.

4. For single-celled, and small organisms, changes in the external environment are more likely to affect the internal environment of the cell directly. Larger plants and animals have developed internal fluid media which become the immediate environment of the tissue cells. This internal medium is regulated chemically by breathing organs (lungs and gills, for example), digestive systems (adding nutrients), and excretory organs (skin glands, lungs, gills, and kidneys, for example). Therefore, the body fluids act as a buffer between the cells and changes in the external environment of larger organisms. Because of this they can tolerate much greater ranges of external environmental change without significantly changing the internal environment. Failure to regulate the internal body fluids will result in sickness and death of the organism if placed in environments directly stressful to the cells themselves.

B. Effects of the Physical Environment

1. Heat. Possible temperature ranges from absolute zero (-273°C.) to the heat of the sun (about 25,000°C.). In this range living things can tolerate generally temperatures between 0°C. and about 70°C. A few molds are known to grow below 0°C., but only a few thermophilic bacteria and algae seem to tolerate temperatures above about 45°C. Man has a "normal" oral temperature of 98.6°F. (about 37°C.). Fevers may raise this to about 105 or 106°F. in the mouth, which means a temperature at the liver of about 115°F. (more or less) which is about 45°C., the temperature at which proteins are denatured. Sunstroke is another heat effect. For some types of surgery (open-heart surgery, for example), the patient may be packed in ice to lower his body temperature to about 68°F., but a little below that, enzyme reaction rates are slowed down so much that metabolism is interrupted and the patient may die.

2. Radiation. The most important radiation is usually that of visible light, mostly from the sun. In Exercise 28 the importance of light has been demonstrated for growing plants. Except for the growing of foods eaten by animals, in the main, larger animals are not so dependent upon visible light for physiological health. (Vitamin D, generated from cholesterol in the skin under the influence of ultra-violet light, can be supplied in the food.)

Ultraviolet radiation of wavelengths 3000-4200 Å (see Teacher's Guides to Exercises 3 and 6). This UVL is responsible for tanning (Vitamin D production) and sunburn in lightly pigmented people. Since UVL is harmful to tissue cells, such devices as feathers and hair are used by higher animals to screen it out. Some people (Blacks, for example) increase the amount of melanin pigment produced when exposed to UVL, so that they darken when exposed to sun. This causes them to absorb and retain more solar heat and, therefore, sweat more profusely in an attempt to keep internal body temperature down.

In one-celled organisms, UVL may penetrate sufficiently to alter the genetic material. For larger organisms, X-ray and gamma-irradiation can penetrate sufficiently to affect the genetic material, breaking up the hydrogen bonds of the nucleic acids so that they become rearranged, that is, mutated (changed).

3. Gravity. This is important to most higher plants, and is important to animals for their orientation with respect to the ground. Space travel has increased the possibility and importance of living things being subjected to weightless conditions.

C. Effects of the Chemical Environment.

1. Water. Water is the basic essential for living things (see Teacher's Guide to Exercise 9.).

2. Nutrients and Wastes. Free-living cells have to move from areas of high wastes and low food to areas of low wastes and, hopefully, high

food. Larger animals do this on a macroscale, finding farming and hunting grounds, disposing of wastes locally, except man, who also constructs sewage systems.

3. Salts are important for the maintenance of transmembrane voltages. This is such a universal fact that transmembrane voltage in a cell could be taken as a characteristic of living things.

Films and Film-Loops (See Section I)

Discussion Questions

1. What inferences of important factors can be made from your general biochemical knowledge? (Consider photosynthetic equation, ATP, and amino acid "protein.")
2. Three physical influences that affect life activities are listed below. Tell how each affect the life of some organism--light, moisture, temperature.
3. If the nitrogen cycle is complete, why must we fertilize farm crops periodically?
4. Why does fertilizer often contain some ammonia and nitrate as well as nitrite?
5. Of what significance is the presence of N-fixing bacteria?
6. Every living thing is surrounded by a "fluid" medium, either air or water. What are some of the advantages of a water medium?

Self-Test

1. Light is essential for the first processes of photosynthesis. (True or False)
2. There is competition among plants as well as animals. (True or False)
3. By definition, the abiotic environment of an organism includes all the living things that affect it. (True or False)
4. An organism is adapted to one fixed environment. If the environment changes, the organism must become extinct. (True or False)
5. Which of the following would be an aspect of the biotic environment of an organism?

   a. Light
   b. Air
   c. Climate
   d. Plant population

(For answers to self-test see page 8-25)

III. Species and the Biotic Environment

Specific References:

Buchsbaum and Buchsbaum (1964), Chap. 3, pp. 39-57
Odum, Eugene (1966), Chap. 7, pp. 112-141

As a rule of thumb organisms interact with each other. Thus, the members of one population may eat members of the other population, compete for food and space, and excrete harmful waste. Population's interactions may be positive, the interaction being either one-way or reciprocal.

A. Population Ecology is a study of a monospecific group of organisms occupying a particular space. The unique properties of a population are density, natality, mortality and age distribution.

1. Density is the size of a population in relationship to some unit of space (2,000 blackbirds per 10 acres of land, for example).
2. Natality is a term used to cover the production of new individuals of any organism whether such new individuals are born, hatched, germinate or arise by asexual processes.
3. Mortality refers to the death of individuals in the population.
4. Age Distribution is an essential population characteristic which influences both natality and mortality. Mortality usually varies with age and reproduction is quite often restricted to certain age groups.

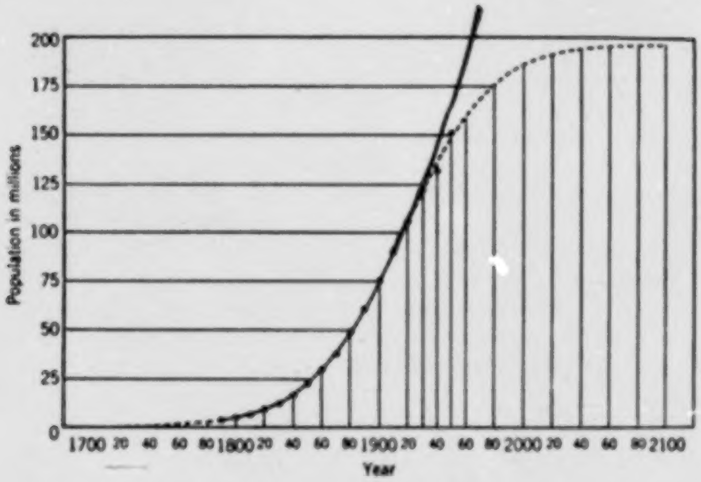
In the unit on the Nature of Science we discussed the anatomy of graphs. At that time students were allowed to draw and analyze graphs. Have a student come to the board and draw a graph that illustrates a very slow increase in a number of organisms, followed by a sharp increase that gradually levels off. (See Robert Anthony's report on p. 8-33.)

We can begin to define and discuss population. In discussing the shape of the graph the teacher can ask some questions such as:

1. What might be some factors that influence the changes in the population growth rate?
2. What factors might have caused the population growth rate to level off and then decrease?

After a discussion of these few questions the students should have covered such topics as food, space, disease, predation, death rate and birthrate. To reinforce the discussion it should be followed by a laboratory activity: Exercise 42 in Laboratory Activities for Biology.

Ask students to bring in for discussion a graph on the growth of U. S. population including the years 1700 to 2000. The teacher will provide the necessary statistics. (see below)



Growth curve of the population of the United States, showing census counts from 1790 to 1950. The logistic function has been fitted to the counts from 1790 to 1910 and extrapolated to 2100. The agreement of the extrapolation with the counts for 1920 to 1950 is shown and a cessation of growth about the year 2100 is indicated (Modified from Pearl, Reed and Kish, 1940). However, the 1970 census shows a population of 210 million as indicated by the solid line extending off the graph.

B. Co-action and Special Species Interaction. There are few plants or animals that are not inhabited by other organisms. Such interactions are commensalism, mutualism, parasitism, competition and predation.

1. Commensalism is an association in which one group of organisms is benefited but the other is not affected.

2. Mutualism is an association in which both groups of organisms derive benefit and neither can survive under natural condition without the other.

3. Parasitism is an association in which one group of organisms derives all of its nourishments from the other organisms.

4. Competition is an association in which each group of organisms adversely affects the other in the struggle for food, nutrients living spaces or other common needs.

5. Predation is an association of populations in which one population adversely affects the other by direct attack but is dependent on the other.

Approach

The teacher may ask several discussion questions such as:

a. Are organisms an island in a community?
b. How is it possible for a cow to digest grass?
c. What would happen if the termites were cured of their flagellates?
d. What is the relationship that exists between the tick bird and crocodile?

After a considerable amount of dialoguing, topics such as predation, commensalism, parasitism, and mutualism should have been covered.

Discussion Questions

1. It is sometimes said that the science of bacteriology is partly responsible for the present population explosion. How can such a statement be justified?

2. An ecologist traps 200 rabbits in area D. He tags all the 200 rabbits and releases them unharmed. One month later he again traps 200 rabbits in the same area. He finds that 20 of them carry the tags he attached a month earlier. How can he use this data to estimate the total population of area D?

3. Why is it important for a bacteriologist to prepare a subculture regularly?

4. What are some factors that could cause the population growth of a given species to slow down? Explain why each might be effective in doing so.

5. What caused the great upsurge in rate of increase of the human population beginning around 1700 and continuing to the present?

6. Explain the difference between the two items in each pair listed below:

   a. Mutualism and Symbiosis
   b. Parasitism and Predation
   c. Mutualism and Commensalism

7. Discuss the connection between the Malthusian theory of population growth and the Darwin-Wallace theory of natural selection.

8. State a conclusion that an ecologist might reach from the data presented in each of the following cases:

   Case I - A count of pine trees shows 500 per acre in area A and only 10 per acre in area B.

   Case II - A count shows that area C contains 20,000 deer but only 250 mountain lions.

9. What is symbiosis?

10. Give some examples of mutualism.

Films

World in a Marsh
Population Ecology

Other Activities

1. Project an old map of tsetse fly distribution in Africa and discuss the low human population density. Attempt to show correlations between the tsetse fly distribution and the following: (1) incidence of trypanosomiasis - the African sleeping sickness and (2) resistance to malaria in those parts of the world.

2. Have the student write a paper on Competition - Man vs. Insect, Mice & Fungi, etc.

Self-Test on Species and Biotic Environment

Completion

1. A population seems to remain static if the ____________ equals the ____________.

2. Copy the following statements and complete them by adding whatever words are necessary.

   a. A rising animal population can indicate that ____________.
   b. The population density of a species is a measure of the ____________.
   c. A falling population can indicate that ____________.
   d. A growth curve of microorganism is often shaped like the letter ____________.
   e. The present population of the earth is about ____________ people. It is estimated that by the year 2000 the population will rise to about ____________ people.

True-False

3. A population is the sum total of all organisms occupying a given environment.

4. With a very few exceptions predators are all animals.

Multiple Choice

5. Barnacles sometimes attach to the skin of whales, by virtue of which they derive benefits without harming the whales. This is an example of (a) mutualism (b) commensalism (c) parasitism (d) adaptability (e) competition.

Answers to Self-Test of Section II.

1. True
2. True
3. False
4. False
5. d.

Answers to Self-Test of Section III.

1. birth rate - death rate
2. a.
    - b. birth rate is greater than the death rate
    - c. increase death rate
    - d. a ∫ (Sigmoid)
    - e. (1) 2.2 billions (2) about 3 billions
3. True
4. True (note: are diseases predators?)
5. (b) commensalism

IV. Pollution

Specific References:

A.I.B.S., Pollution: Is there a solution?
A collection of reprints from Bioscience, 18(7), and 19(10 and 11):
__________. Available from the American Institute of Biological Sciences, 3900 Wisconsin Ave., Washington, D. C. 20016
The following articles from Scientific American, Vol. 223(3) Sep. 1970:
Human Food Production as a Process in the Biosphere by Lester R. Brown - The advances of agriculture yield a larger human crop, pp 160-173.
Human Energy Production as a Process in the Biosphere by S. Fred Singer - The release of stored energy races the cycles of nature, pp. 174-193.
Human Materials Production as a Process in the Biosphere by Harrison Brown - Closing the cycles of inorganic materials is difficult, pp. 194-208

Alternate References:

Kormondy-Concepts of Ecology, pp. 166-196
Ecology - Life Nature Library
Johnson ed. No Deposit--No Return, pp. 18-35, 108-140, 152-155
McClellan ed. Protecting Our Environment, pp. 9-17, 26-46, 89-94,100-122, 132-13
Science, November 14, 1969 - editorial by Rene Dubos
Editor of Ramparts Magazine - Eco-Catastrophe, pp. 1-15
Bresler, Jack B., Environments of Man
Battan, The Unclean Sky
Benarde, Our Precarious Habitat
Goldman, Controlling Pollution
Carson, Silent Spring
(See also magazine articles listed under Approaches)

A. Objectives and Introduction

The purposes of this section would include:

1. Broadening the awareness of students to the need for a clean environment.

2. How man's interaction with his environment is tied up with his survival.

3. Social and political actions in food production energy, energy resources materials in which citizens may participate to bring about better pollution control.

Introduction

1. The accumulation of wastes in cells, such as pigments in nerve cells and hemosiderin in lung cells, appear to contribute to aging in these cells. Therefore, prevention of waste accumulation would contribute to longer life. This is more easily demonstrated in a culture of yeast cells (See Exercise 42) where, after the growth

phases are completed, the accumulation of wastes in the surrounding medium will lead to the death of the culture.

The unfavorable alteration of our surroundings, wholly or largely as a by-product of man's actions, results from the conversion of large quantities of natural products into corresponsingly large quantities of waste products. Since all ecological systems must be self-regenerating with respect to energy and materials, man must somehow learn to recycle rather than to discard his waste products.

2. Man depends on the earth for his food, clothing, housing, industrial plants and machines, energy resources such as coal, oil and isotopes for producing heat and electricity. The misuse of natural resources will lead to their premature exhaustion and that will lead to the end of these facets of modern culture.

   The fact is that it is the environment that takes care of man, so that excessive contamination of the environment (air, water, land, forests, etc.) prevents nature from caring for man.

3. It will not be enough for this unit to point out the ways in which the environment must be preserved so that the food chain, the energy chains and the resources chains which benefit man can still function. It must also take note of the ways in which students, as citizens and as members of society must use their enlightenment to help guide social and political philosophy regarding the conservation of natural resources, the maintenance of the human and biological environment in a suitable state of purity so that nature can pursue the work of keeping life a continuing state of being, and provide surroundings for the economic, esthetic, and recreational uses of mankind.

B. Approaches

This section lends itself well to an interdisciplinary approach. One of the themes in the TCCP English curriculum is responsibility. The issue of pollution control is clearly an issue of personal and public responsibility. It would be easy, if planned early, and beneficial to the student to look at this issue in both his science and his English class.

There are several ways this section can be approached using the interests and talents of various students to get at the issues of what pollution is, what damage it has done, and what has been and should be the reaction of the individual and of society to the problems caused by pollution.

1. The students can be given a series of quotes similar to the examples listed below and asked to write or respond verbally to them. This could be given as a homework assignment, asking the students to be prepared to discuss, defend or critize them.

a. "In defying nature, in destroying nature, in building an arrogantly selfish, man-centered, artificial world, I do not see how man can gain peace or freedom."
Marston Bates - The Forest and The Sea

b. "We must make no mistake. We are seeing one of the great historical convulsions in the world's fauna and flora."
Dr. Charles Elton

c. "We cannot command nature except by obeying her."
Francis Bacon (17th Century)

d. "Man has lost the capacity to foresee and forestall.
He will end by destroying the earth."
Dr. Albert Schweitzer

e. "Nature's polluted
There's man in every secret corner of her
Doing damned wicked deeds. Thou art, old world
A hoary, atheistic, murdering star.
Thomas Beddaes (19th Century English poet)

f. "The earth also is defiled under the inhabitants thereof....
Therefore, the inhabitants of the earth are burned and few men left
And all her princes shall be nothing
And thorns shall come up in her palaces, nettles and branches
in the fortresses thereof, and it shall be an habitation of
dragons and a court for owls."
Isaiah 24:5,6;34:12,13

Tom Lehrer's song "Pollution" from his record "That Was the Year That Was" (also, reprinted in Controlling Pollution by Goldman) could be a novel way of introducing the topic.

2. Ask the students to check newspapers and magazines for stories related to the problem of man's effect on his environment. The teacher could begin by bringing in some news headlines from last year's nation-wide Earth Day (April 22, 1970) and by discussing what, if anything, was done at your own school at that time.

Some recent issues of popular magazines carrying pertinent articles:

Look Magazine, November 4, 1969, America the Beautiful by David Perlman
Look Magazine, September 9, 1969, The Assault on the Everglades by A. Wolff
Life Magazine, August 1969, Threatened America by D. Jackson
Readers Digest, February 1969, America the (Formerly Beautiful) by J. Miller
Readers Digest, May 1969, The Great American River Cleanup by W. Langewiesche
Playboy, July 1970, Interview with the Biologist-Ecologist Paul Ehrlich

3. In order to make the problem of pollution as relevant as possible, students should be encouraged to look around their neighborhoods and/or city for evidence of how man has ruined the landscape, destroyed natural resources and polluted his air and water. Photographs documenting these can be taken and a series of slides or prints that tell the story can be put together.

4. In the same vein as the above, making the problem personally meaningful, the class could try to find out what your city is doing about pollution control. If possible, speakers from local government should be invited to address the class on the issue. (Before this is done students should have a knowledge of the problems in their area, a field trip would be appropriate here, and be armed with specific questions for the government representative.)

   Information, and possibly speakers, can be gotten by contacting:

   Local conservation officers
   Environmental Control Services Administration
   Civil Defense Office or the Atomic Energy Commission for information on radiation

5. Students interested in the legal aspects of pollution control could try to compile a list of major national and local legislation that has been passed recently in response to rising concern with the problem. Questions to be asked include:

   a. Has this bill been successful in controlling pollution?

   b. How are the measures it suggests to be enforced?

   i.e., Water Quality Act,1965
   Clean Water Restoration Act,1966
   Air Quality Act,1967
   Wilderness Act,1964
   Radiation Control for Health and Safety,1968

If there is enough enthusiasm generated by one or a combination of the above activities, it would be useful for understanding what the individual can do to control pollution to actively involve the class in a community cleanup project. Perhaps the photo series, or the field trip, or information from the local government representative has pointed out an area accessible to group cleanup effort; i.e., a neighborhood park, a local beach, a dump near the school grounds - any project that the students decide on and organize should be highly encouraged.

In Neolithic times (10,000 years ago) man first emerged as the only animal that set out to subdue his environment instead of to adapt to it. We can say that we have been extraordinarily successful; ecologists argue that we have also been extraordinarily lucky in that nature has been able to compensate for our mistakes. But they have sounded the warning that this may no longer be possible; that

The interacting effects of unchecked population growth, industrial and agricultural expansion, and because technological advances are straining the limits of the ecological balance that we take so much for granted. We can see this through an in depth study of air and water pollution as well as an understanding of other ways man has effected the balance; i.e., by causing animal extinction, depletion of natural resources and misuse and overuse of the wilderness.

C. Types of Pollution

1. Air pollution

a. Smoke. The same cancer-producing (carcinogenic) chemicals found in cigarettes are found in polluted city air. It has been estimated that a person breathing the air of the average big city for 24 hours, inhales as much carcinogen as he does from one package of cigarettes per day. (During a recent air inversion over New York City, when the concentration of pollutants drastically increased so that breathing for 24 hours was equivalent to smoking two packages a day, it was suggested that soon our cities would have to post signs saying "Beware, breathing in this city may be hazardous to your health.")

b. Radiation. Until the 1945 atomic blast at Alamagordo, no animal in a natural environment had been exposed to the effects of radiation beyond a natural low background level. After an atomic test radioactive material drifts down to earth, penetrates the soil and water and is absorbed by organisms and concentrated in their tissues.

Although the quantity of the fallout is a problem today, the one of greater concern is the way some long-lived radioactive particles become concentrated in the bodies of animals at the top of the food chain. Two examples can be cited:

(1) Radioactive Strontium 90 is absorbed by cattle as they graze on contaminated grass. Strontium 90 is passed on to man in milk and cheese and is concentrated in human bone. This could be a cause of leukemia or of bone cancer. Recently it has also been shown that breast milk contains a higher level of Strontium 90 than allowed in store-bought milk.

(2) Radioactive Cesium 137 is picked up by man directly from vegetables and is concentrated in such soft tissues as the liver and the gonads. If this will or has caused gene damage, has not yet been determined.

c. Insecticides. Each year more than 600 million pounds of pesticides of all kinds are sprayed, dusted, fogged or dumped in the U. S. (about 3 lbs. per person). Dangerous levels of deadly pesticides are found in plants including tobacco and fruit,and several species of animals, including the American bald eagle,which are being threatened with extinction by pesticides.

In addition, by using insecticides, we have broken down the natural relations and allowed normal pest regulating machinery to get out of hand. (A fascinating and easily readable prediction of the possible effects of insecticides can be found in the article by P. Ehrlich in Eco-Catastrophe.)

Air pollution is, therefore, a result of high levels of industrial gases,insecticides and radioactive materials. Air pollution has lead to an increase in the death rate, colds, heart disease, emphysema, cancer, as well as to property damage in both cities and farmlands.

2. Water pollution

Water purifies itself by depending on the microbes that live in it to destroy the organics it receives. By putting too much organic matter in the rivers, the microbes will draw out all the oxygen in the water in order to decompose the matter. After this point the beneficial microbes can't live and the river loses its power of self-purification.

Today every major watershed in America has been polluted by the unchecked expansion of business and industry and the associated industrial wastes they pour into rivers and by the unwillingness of the local communities to clean their wastes adequately before dumping them.

a. Detergents. Unlike soap, most detergents resist bacterial action which might decompose them and they may circulate in water supplies for years. This is because detergents, until recently, have contained synthetic branched carbon chains as the backbone for their fatty acids. Since naturally occuring enzymes preferred the unbranched chains found in natural systems, the detergents were not attacked or degraded.

   Phosphorus in detergents is also a problem. Algae in the water use phosphorus to grow. They cause an unpleasant taste and smell in water and their decomposition upon death draws on a lake's oxygen supply and diminishes it.

b. Raw Sewage. Raw sewage introduces gross impurities, disease germs, salts, acids, dyes, phenols, insecticides, medicines, fertilizers and other chemicals into the lakes and rivers.

c. Oil Pollution. Although the short-term effects of crude oil found in increasing amounts in the oceans due to spillage and waste appear to be limited, except for the destruction of water fowl, - chronic pollution poses a threat to marine life, the fishing industry, recreation, the habitat of animals and plants in the tidal zone and along the shore. The insidious nature of water pollution can be clearly illustrated by the findings that seabirds are now in general more contaminated with agricultural and industrial pollutants than are land birds.

3. Other ways man has affected his environment

   a. Animal Extinction. Since 1600 we have eliminated through extinction more than 350 species and races of birds and mammals. Now,more than 800 other species and races are known to be endangered. As we simplify, reduce or eliminate natural diversity, we reduce our chances of survival since the atmosphere, the water and the soil have been maintained by the once enormous variety of species on the earth.

   b. Exploitation of Natural Resources. Such non-renewable resources as mineral fuels, metals, and industrial minerals and rocks are already in short supply and known resources of others will be exhausted within two to three decades. Man's efforts in getting the natural resources have left scarred slopes and debris-filled valleys, soils unable to sustain plant life, burning coal mines and waste piles and a caving or subsiding ground that is unsafe to build upon.

   c. Overuse and Misuse of Open Spaces. One of the most visible of man's insults on his environment is the rapidly vanishing wilderness and the "uglification" of the land we have settled. Only through the concerted efforts of conservationists has the Grand Canyon been saved from flooding by the introduction of a dam, and the California redwoods been rescued from the saws of the lumberjacks. But the forests and the canyons, as well as the parks, camp grounds, and mountains are all feeling human presence in the piles of garbage we leave behind us. Wilderness is not susceptible to compromise - once it is destroyed, it can never be reborn.

D. Pollution Control

The technology that has produced the environmental degradation we see today has developed rapidly, too rapidly to permit the inclusion of environmental values in the planning scheme. A new technology devoted to a recycling process is essential if man is to continue to breath, live and survive.

The role of the individual vs. the role of the institutions of society; i.e., government, industry, law and education should be discussed. Who is to make the decisions about what is to be done? How will they be enforced? What is the role of the scientist, teacher, businessman, economist, lawyer, and private citizen?

A Classroom Account by Robert J. Anthony, Jackson State College

Teaching techniques used to cover the unit on Ecology were designed to entice the students to become active learners, to provoke them to think through problems, and to encourage them to set up and defend hypotheses.

Holding to the above procedures as major premises, I began the unit on Ecology by presenting the class with a miniature community. The miniature community was made by filling a three-gallon bottle about one-half full of pond water, adding a small amount of soil and a small amount of algae from a pond. After the soil was settled and the water cleared, I added several sprigs of elodea. Later, I introduced minnows, a snail or two and a piece of clam shell (to neutralize acid wastes) and the bottle was corked airtight. Students were then asked leading, thought-provoking questions. One of the many questions asked was, "Why will the minnows live for several months?"

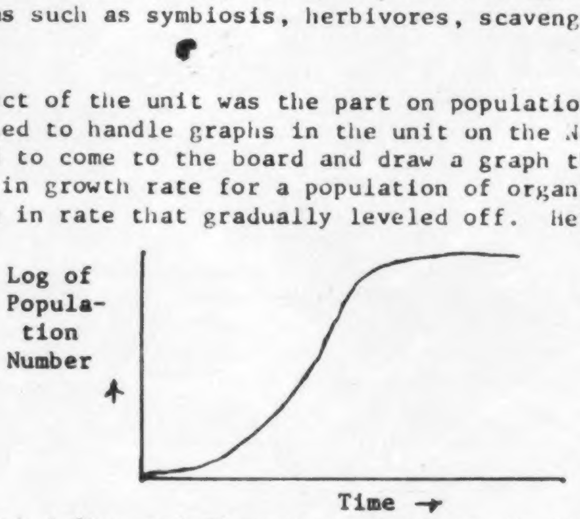
Student A	said that the plants served as food for the fish.
Student B	said the plants produced oxygen.
Student C	said the animal produced carbon dioxide that is used by the plants to make food.

They were then asked to devise an experiment to test their assumptions.

Through this type of deliberation we discussed with understanding the role of plants and animals in a given area. It also gave the student a working definition of ecology. Students became so excited about ecology, until they read all about the community in Buchsbaum's Basic Ecology.

To afford further meaning to what the student and I had discussed, we took a field trip to the Botanical Gardens on campus, and we visited a small pond. Here, students were able to observe and study an actual environmental setting. They were required to record information obtained from the field and use this data to construct a diagram of a food chain, and to explain certain other ecologically-associated terms such as symbiosis, herbivores, scavengers, decomposers, carnivores, etc.

Another interesting aspect of the unit was the part on population ecology. Since the students had learned to handle graphs in the unit on the Nature of Science, a student was asked to come to the board and draw a graph that illustrated a very slow increase in growth rate for a population of organisms, followed by a sharp increase in rate that gradually leveled off. Here is the kind of graph he drew:



From the graph we began to define and discuss population. In discussing the shape of the line, I asked some questions such as: "What might be some factors that influence the changes in the population growth rate? What factors might have caused the population growth rate to level off and then decrease?" By discussing these questions we covered in some detail such topics as food, space diseases, pollution, predation, death rate and birth rate.

The topic that really stirred up the students' interest was the one about war being a necessary evil. Many of the students did not think it was necessary, however, there were those who felt wars served as a population control.

The students did the laboratory activity (Exercise 42) on following the growth of yeast in a 5% aqueous sugar solution. For a week they took samples of the culture periodically, did cell counts, and constructed a growth curve that was fairly sigmoid. As a result of this laboratory activity, I was truly satisfied that the students really understood many principles of ecology that had been introduced.

A Classroom Account by Robin Griffith of Norfolk State College

The students were asked to come prepared for a field trip to the wooded area behind the school. Before leaving they were given an outline of the kinds of things to be aware of and record while they were collecting plant and animal specimens; i.e., light conditions, soil mixture, evidence of competitive relationships, examples of dependency between plants.

I was skeptical of using such a trip to get the students involved in the whole area of Ecology. I felt, however, that it turned out well because of the students' natural curiosity and willingness to see things in new ways, to look at leaves and leaf arrangements, to dig under rocks and in decaying logs to begin to see the interaction between a plant or an animal and its environment. We brought our "finds" back to the laboratory, along with notes on where they were gathered. A discussion of the physical and chemical environment of a species, the concept of biome, of food chains and webs, of the factors that control population size followed easily from our collective experiences in the field. I have just begun to review the student reports of this trip and hope to get some specific examples of the student attitude towards it. My feeling at the moment, however, is that a poor background in field biology should not discourage a teacher from exposing his students to a field trip. I got the impression this summer that many laboratory-oriented teachers were loathe to go into the field.

The students see biology in a new light since many had never thought of field biology as legitimate biology. Furthermore, the whole field of ecology can be developed from such a beginning. Since pollution was evident on this trip, as it would be on most field trips, we also have a natural lead into this week's topic, a discussion of pollution, what it is, who causes it, who's responsible for it.

A Classroom Account by Jimmie L. Col of Alabama A and M State College

The field trip was taken in connection with Exercise 38. The purpose was to study the interrelationships of plants in a forest. The students measured the coverage; trees, shrubs, saplings, herbaceous plants, and tree seedlings.

Our forest is really on the campus, just behind the administration building. The students spent their regular two-hour class period finding out what they were expected to do in the forest. The students were in groups of four or five. They were instructed to go back to the forest in groups to complete their work. Some went during the school day, others on Saturday.

After the groups had ample time (one week) to complete their observations, we discussed their findings in class.

A Classroom Account by Mrs. Elizabeth D. Clark of North Carolina A and T Univ.

I regularly organize a six-week project on hormonal control in chickens. I found that the project leads the students into many other areas of biology, as illustrated below:

The students had cleaned out the chicken lab for three days and carried out the waste but it had not been collected. The number of flies continued to increase. One student said, "We can spray the waste and kill the flies. Another said, "What if some of them fly into the lab. If the chickens eat these flies they may die. I saw on the TV where birds ate insects that had been sprayed with insecticide and died. We spray a lot around our kitchen. I'm sure that the spray does not effect man." The discussion continued, "Maybe the insecticide loses its toxicity after a short time. It is sprayed directly on the fly and kills the fly immediately." "Well, we spray the entire surface of flies so they can't get air, therefore, they die. Some of it must get into the bodies of insects that eat the insecticide. I wonder what really happens. At this time I suggested that this would make an interesting library research problem. They could check the Scientific American and other scientific journals for related materials. They could also write to research laboratories for literature concerned with pollution.

Just before final examinations the discussion went from insecticides to smoke and smog. The students mentioned cancer and other respiratory conditions. They asked if I had ever seen body tissues affected by smoke. I did not know what they had in mind exactly so I told them of an experience I had as a pathological technician. The doctor had removed a portion of the lungs from a corpse for autopsy. The lung sacs were filled with black grit I actually scraped some of it out on a paper with a dissecting pin. I had to make sections from this specimen for histological study. The grit was probably from habitual smoking and pollution.

I asked how many major areas of pollution did we have in and around Greensboro. I suggested that I would like to have those with cameras to help me develop a set of slides for discussing pollution. We started with the smoke stacks at the heating plants of A. and T. and Bennett College. During the winter the neighborhood is black with hanging clouds of smoke especially when the buildings are first being heated. There is a sulfur and fertilizing plant that covers adjacent areas with dense yellow clouds and frequently the ground is covered with yellow material. We will get these scenes in September. I asked the students to continue to take pictures of polluting situations such as smoke polluting the air or waste being spilled into streams from factories. They are to list names, places and dates; and, if possible, comments on the homes and plants in the area.